PB-227 057

SALINITY CONTROL INTERIM REPORT FOR WATER SUPPLY AND WATER QUALITY CONTROL STUDY BRAZOS RIVER BASIN-TEXAS

Environmental Protection Agency
Dallas, Texas

March 1973

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ENVIRONMENTAL PROTECTION AGENCY
REGION VI
DALLAS, TEXAS

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN-TEXAS

Abstract

A study was made which discloses that the quantity of salts collected and transported by the Brazos River can be substantially reduced by construction of control projects proposed by the Corps of Engineers. Construction of salinity control project (Plan 4A) will reduce mineral concentrations sufficiently to allow use of water resources in the entire stretch of the main stem in and below Possum Kingdom Reservoir for potable water supplies.

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I. INTRODUCTION

Request and Authority

In a letter dated May 3, 1963, the Fort Worth District, Corps of Engineers, Fort Worth, Texas requested the Public Health Service to assist the Corps of Engineers in their study of the water resources of the Brazos River Basin by determining "the municipal and industrial water requirements, the quality of water, the extent of existing and potential pollution, as well as the need for and the benefits from conservation storage for purposes of municipal and industrial water supply and water quality control."

In a planning conference September 1, 1967, the Corps of Engineers requested that an interim report dealing specifically with salinity control, be prepared prior to completion of the comprehensive study. This interim study is the first increment of the total requested work.

Responsibility for completing the study was transferred to the Environmental Protection Agency after three organizational changes. Effective December 31, 1965, Section 2 of the Water Pollution Control Act, as amended by Public Law 89-234, established the Federal Water Pollution Control Administration as an operating agency of the Department of Health, Education and Welfare. Under Reorganization Plan No. 2 of 1966, the Administration was transferred to the Department of the Interior, effective May 10, 1966. Under Reorganization Plan No. 3 of 1970, the Administration was transferred to the Environmental Protection Agency, effective December 2, 1970.

The study has been conducted in accordance with provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C. 466 et seq.) wherein authority is given to conduct investigations relating to the causes, control, and prevention of water pollution.

Purpose and Scope

Due to high mineral content, use of water resources in certain areas of the Brazos River Basin is severely restricted. This interim report was prepared to define future water demands and to describe the extent of mineral pollution and the feasibility of reducing the mineral content to levels that would allow less restrictive water use. Only a portion of the information requested by the Corps of Engineers for their comprehensive study of the full development potential of water resources in the Brazos River Basin is presented.

This report was prepared from an analysis of basic data available in the Environmental Protection Agency files and data supplied by other agencies; no field studies were conducted. A mathematical model of the stream system was constructed to simulate surface water properties throughout the basin. This model was used to predict the affect of various salinity control plans on surface water supplies under projected conditions of water resource development. The model is discussed further in Appendix II.

Acknowledgments

The assistance and cooperation of agencies and individuals who aided in the assembly of data for this report are gratefully acknowledged. Special appreciation is expressed to the following:

1. Brazos River Authority - Waco, Texas.
2. Texas Water Development Board - Austin, Texas.
3. United States Geological Survey - Austin, Texas.
4. United States Army Corps of Engineers - Fort Worth, Texas.

Note

All references to study area, tables, figures and appendices pertain to the Environmental Protection Agency Report. This note is included to prevent confusion where this report is later published as an appendix of the Corps of Engineers Report.

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The study area in Texas comprised of 64 counties, partially or wholly in the Brazos River Basin and the Brazos-San Jacinto Coastal Basin, increased in population from 1,541,714 in 1960 to 1,672,919 in 1970.

2. The study area includes a 46,080 square mile drainage area of which 44,280 square miles are in the State of Texas. The portion of the basin in New Mexico and on the High Plains of Texas, a total of 9,240 square miles contributes very little runoff to the Brazos River.

3. The climate of the study area is typically humid in the eastern part and semiarid in the western part while in the midsection alternation between humid and dry is typical. Mean annual precipitation ranges from 18 inches to 48 inches across the study area. Two peak rainfall periods are evident with the greatest rainfall during the April, May, June period and the second largest rainfall during the August, September, October period.

4. Exclusive of the Ogallala Formation, a perennial yield of about 505,000 acre-feet of fresh to slightly saline groundwater could be withdrawn from primary and secondary aquifers in the Brazos River Basin and the Brazos-San Jacinto Coastal Basin.

5. Groundwater quality is highly variable, however, it can be generally stated that the mineral content of the greater portion of the groundwater supplies of the study area exceeds maximum limits recommended in the U. S. Public Health Service Drinking Water Standards.

6. Flow measured at river mile 93 (USGS Gage 1140 at Richmond) averaged 7740 cfs (5,607,320 acre-feet per year) for the period water years 1941 to 1962.

7. Total 1960 water use in the six sub-areas of the study area was 4,963,100 acre-feet.

8. Water resources of the Brazos River Basin that are transported in the main stem channel are severely damaged by mixing with highly mineralized runoff collected in the headwater areas.

9. Poor quality of water in the upper basin is due principally to:

   a) natural mineral pollution (inflow of natural sodium chloride brine, particularly in Salt Croton Creek, a tributary to the Salt Fork; and solution of calcium sulfate from the gypsiferous rocks and soils that are at or near the surface throughout much of the area).

   b) manmade pollution of streams by the disposal of salt water produced with oil. Although the pollutants from present day oil production are properly handled, minerals discharged in past days are still being washed into drainage courses. Also, seepage from abandoned improperly plugged oil wells degrades surface supplies.

10. Although the area above Possum Kingdom Reservoir contributes an average of only 14 to 18 percent of the runoff from the Brazos River Basin, this area is the source of about 45 to 55 percent of the dissolved solids, 75 to 85 percent of the chloride and 65 to 75 percent of the sulfate carried by the Brazos River at Richmond, near the mouth.

11. The effect of oil-field brines on water quality in the Upper Brazos River Basin is most evident in the Clear Fork and its tributaries.

12. There are a wide range of adverse economic and public health effects exerted by high levels of salinity in water supplies, but the most readily evaluated indicator of acceptable chloride, sulfate, and total dissolved solids in municipal water supplies is their effect upon the taste and laxative properties of the water, and water that is acceptable from this standpoint is generally considered suitable for most beneficial uses.

13. Waters containing less than 600 mg/l of sulfate generally do not produce laxative affects.

14. Public Health Service Drinking Water Standards for chlorides, sulfates, and total dissolved solids are primarily based on threshold taste tests. Limits have been selected to preclude detectable taste by most users.

15. Consumer attitude surveys show that detectable taste in potable water is not necessarily objectionable.

Conclusions

1. Multiple use of natural resources, in effect, increases the available supply. Where the geography is favorable, waste water discharged by upstream users can be appropriated to satisfy downstream demands. It is projected that by 2020, 369,250 acre-feet per year of waste water will be reused to meet a portion of the water supply requirements.

2. The total yield of water resources expected to be developed in the study area by the year 2020 is 2,184,250 acre-feet per year. This estimate includes yields from existing import projects, groundwater, return flow, reservoirs and a limited supply from uncontrolled streamflow. The estimate does not include withdrawals from the Ogallalah Formation which is expected to be 426,100 acre-feet per year by 2020.

3. Projected water demands (acre-feet) for the year 2020 are - municipal and industrial 1,603,000; irrigation 5,399,700; and mining 7,800. This demand cannot be fully supplied with water resources available in the study area. Imports totaling 4,493,900 acre-feet per year will be needed in subareas 1 and 2. Resources can supply demands in sub-areas 3 through 6 if quality improvements are obtained.

4. Poor chemical quality resulting from salt pollution imposes severe restrictions on use of water in the Brazos River. Improvements in chemical quality will be required to permit effective utilization of the water resources of the Brazos Basin for supplying projected water needs through the year 2020.

5. The mineral content of water resources at any point in the main stem of the Brazos River cannot be reduced below limits recommended in U. S. Public Health Service Drinking Water Standards - 1962 one hundred percent of the time with any of the impoundment alternatives studied. However, very significant reductions in mineral content can be achieved and consumer attitude tests reveal that potable water supplies can be successfully developed where mineral concentrations exceed, within reasonable limits, the maximums recommended in U. S. Public Health Service Drinking Water Standards - 1962.

6. Construction of the proposed salinity control project (Plan 4A) will reduce degradation of main stem resources and mineral quality improvements will allow the resource to be fully used. Brazos River Basin water resources transported in the main stem could be withdrawn from Possum Kingdom Reservoir and at any point below for municipal water supplies.

7. Construction of the alternative salinity control project (Plan 4B) will reduce degradation of main stem resources. Mineral quality improvements will allow full utilization of the main stem resources in and below Lake Granbury. It may also be possible to gain full utilization of resources above Granbury Lake to include Possum Kingdom Reservoir resources through selective pumping and mixing with other supplies.

III. PROJECT DESCRIPTION

Although numerous methods of salinity control in the Brazos River Basin were investigated, discussion in this report will be restricted primarily to the method (Plan 4A) that appears, at this time, to most effectively meet the river basin needs for prudent water resource management. One alternative (Plan 4B) is discussed in Appendix III. Plan 4A involves construction of four reservoirs in the upper basin. These reservoirs will be used to permanently impound all runoff from certain portions of the basin where large quantities of minerals are now carried by the runoff to the main river channel below. Locations of the four reservoirs are shown on Figure III-1 and III-2.

Site 20 is located on the main stem of the Salt Fork of the Brazos River; all other sites are on tributaries. Site 10 is located on Croton Creek, site 14 is on Salt Croton Creek and site 19 is on North Croton Creek.

The reservoirs at sites 10 and 14 will be used only for collection and temporary storage. Water collected in these reservoirs will be pumped into site 19 for permanent storage. The reservoir at site 14 will be dry much of the time. All four reservoirs are adequately sized to prevent passage of any surface flow past the damsites.

IV. STUDY AREA DESCRIPTION

Location and Boundaries

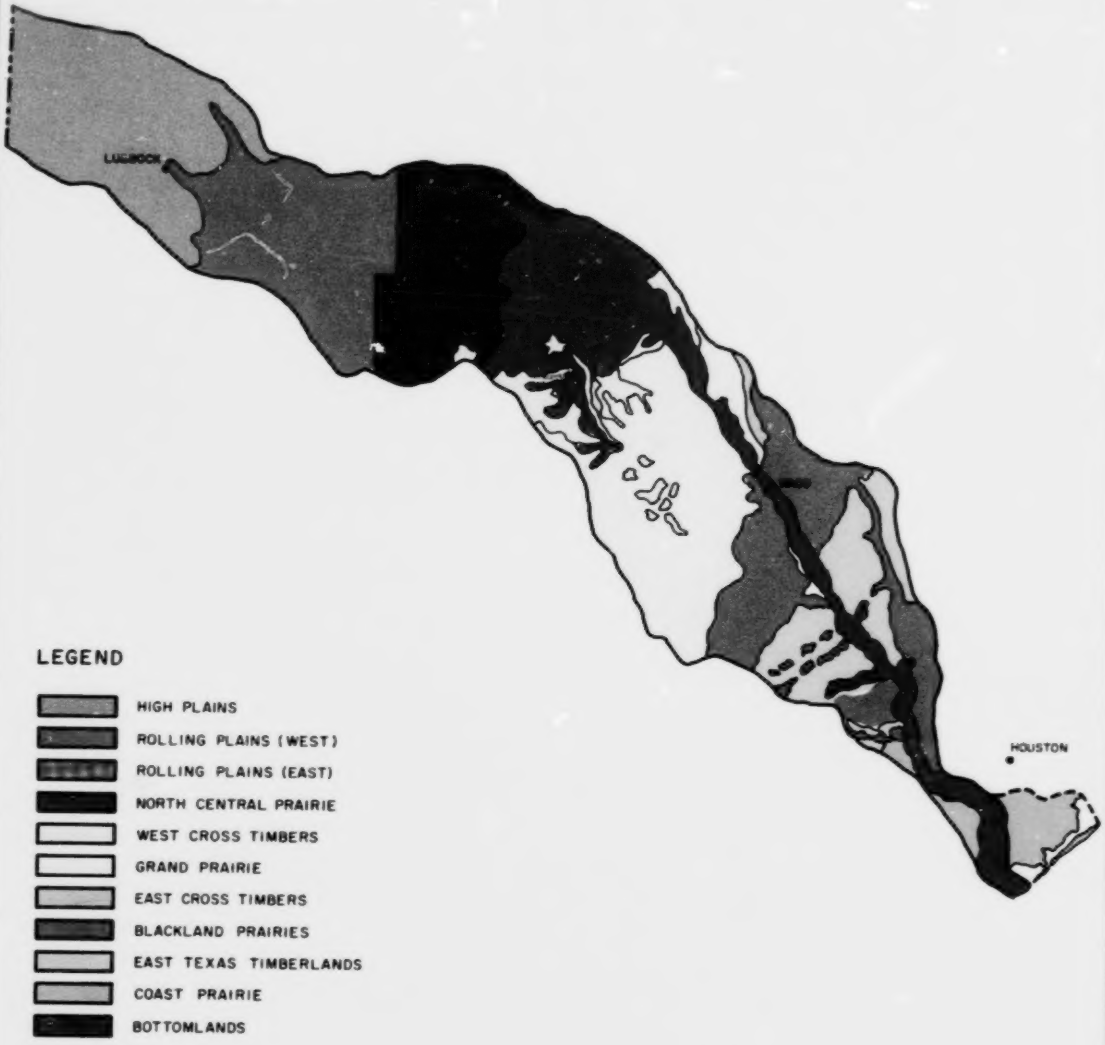
As shown on Figure III-1, the study area includes 64 full counties, in Texas, all or a portion of which are within the basin drained by the Brazos River and the coastal area that drains directly to the Gulf of Mexico and to Galveston Bay between the Brazos and San Jacinto River Basins (referred to hereafter as Brazos-San Jacinto Basin). The study area was divided into six sub-areas shown on Figure III-1 for convenience in planning.

Geography 1/

Climatic and soil conditions vary widely and have resulted in several distinctive patterns of land use. Areas possessing similar characteristics of use are shown on Figure IV-1 as Land Resource Areas. The Land Resource Areas have been given names similar to the physiographic units showing that the origin of soil materials has a major influence on land use. However, more than one physiographic type may be represented within a land resource area. The land resource areas are described below:

High Plains - Soils range almost uniformly from somewhat sandy materials to very loose sands. Extensive groundwater irrigation has made the High Plains one of the major irrigated areas of the United States. Cotton and grain sorgham are major crops on the best soils. Wheat is important on the heavier soils occupying a narrow northern rim in the basin. Shortgrasses are the principal native vegetation. Many of the sandier rangeland soils support dense growth of shin oak and sand sagebrush.

Rolling Plains - A large portion of the Rolling Plains area is native range covered with native midgrasses and shortgrasses. Soils generally are shallow and unproductive on a rolling, well-dissected topography. Bare eroded areas of clayey red bed material are numerous. Rainfall is erratic and supplemental water for irrigation is scarce. Limited areas are used for growing cotton, grain sorghum, wheat, and other small grains. Mesquite, other brushy growth, and some cedar is present on much of the rangeland.


LUBBOCK
HOUSTON
LEGEND
HIGH PLAINS
ROLLING PLAINS (WEST)
ROLLING PLAINS (EAST)
NORTH CENTRAL PRAIRIE
WEST CROSS TIMBERS
GRAND PRAIRIE
EAST CROSS TIMBERS
BLACKLAND PRAIRIES
EAST TEXAS TIMBERLANDS
COAST PRAIRIE
BOTTOMLANDS

SOURCE: THE REPORT OF THE U.S. STUDY
COMMISSION-TEXAS PART II
RESOURCES AND PROBLEMS

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN — TEXAS

GENERALIZED LAND RESOURCE AREAS

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE IV-1

North Central Prairies - Shrubs, cacti, mesquite, and brushy hardwood species cover much of the North Central Prairies. Possibly one-third of the area is open grasslands covered with midgrasses and shortgrasses. Among the rangelands are ridges and bluffs covered with dense non-commercial stands of cedar and scrubby blackjack oak, post oak, and other hardwoods. Ranching is the principal interprise. Growing seasons are hot and dry. Annual rainfall is around 25 inches but is very erratic. Soils are tight and absorb water slowly. Farmland is used largely to grow feed crops, forage and hay.

Cross Timbers (East and West) - Land use and treatment in the land resource areas designated as East and West Cross Timbers are similar. Cross Timbers soils are sandy, acid, loose, and easily eroded. The organic-matter content is low and the soils are relatively low in natural productivity. Small fields of cropland are used largely for growing pasture, hay and feed crops. Much of the area remains in natural stands of short-bodied, slow growing blackjack oak, post oak and other hardwoods. Dairying and poultry raising are important. A considerable number of beef cattle also are raised.

Grand Prairie - Soils in the Grand Prairie land resource area are derived from limestone and other limy materials. Oats and other small grain are raised for both grain and pasture, particularly on the shallow soils. Cash crops, mostly cotton and grain sorghum, are concentrated on the deeper soils of valleys and smooth divides in the northern part where summer soil-moisture conditions are more favorable. Tame pastures and meadows are being developed increasingly. In the southern part of the Grand Prairie the economy is based almost exclusively on livestock raising on small ranches and livestock farms. Confined to relatively small fields of the better soils, croplands provide feed crops and pastures to supplement grazing from native rangeland. The Grand Prairie becomes progressively rougher, steeper, and rockier toward the southern boundary. The native rangeland vegetation is greatly affected by frequent droughts and prevailing hot, dry summer growing seasons. Native bluestems and other midgrasses develop well, however, bunchgrasses and shortgrasses are more common in the southern part of the Prairie. Much of the rangeland has a woody overstory of blackjack oak and post oak, cedar, live oak, mesquite, and other brush. Wooded valley lands contain oak, pecan and other hardwoods. Except for some of the better cedar near the southern edge of the area, the woodlands are non-commercial and are used with adjoining rangeland for grazing.

Blackland Prairies - The black and gray calcareous clay soils of this area are highly productive. Cotton is the most important crop although considerable acreage is devoted to grain sorghum, corn, wheat and oats. Cropland pastures of small grains legumes and several adapted pasture grasses provide sizeable livestock production. The production of chickens, turkeys, and eggs is also important.

Coast Prairie - Heavy clay soils are prevalent in the Coast Prairie and generally are poorly drained. Much of the area is used periodically for growing rice. Large numbers of cattle are grazed on rice fields during the years between periods used for rice and on large acreages of native grass range and improved tame pastures.

Bottomlands - The Bottomlands land resource area includes the alluvial soils along the lower reaches of the Brazos River. The soils have been transported from upstream and are unlike the adjoining area. Frequently flooded areas remain in native vegetation of bottomland hard woods and grass. Both high river terraces and better drained "front" lands along stream courses are high-producing farming areas and are used intensively for production of cotton, corn and other crops. There is a growing acreage of Bottomlands crops that is being irrigated from water pumped from the river or shallow wells in the adjacent alluvium.

Physiography 1/

The study area extends almost 600 miles from the mouth of the Brazos River at the Gulf of Mexico near Galveston, northwest across Texas and into New Mexico near the City of Clovis and includes a 46,080 square mile drainage area of which 44,280 square miles are in the State of Texas. The portion of the basin in New Mexico and on the High Plains of Texas, a total of 9,240 square miles contributes very little runoff to the Brazos River.

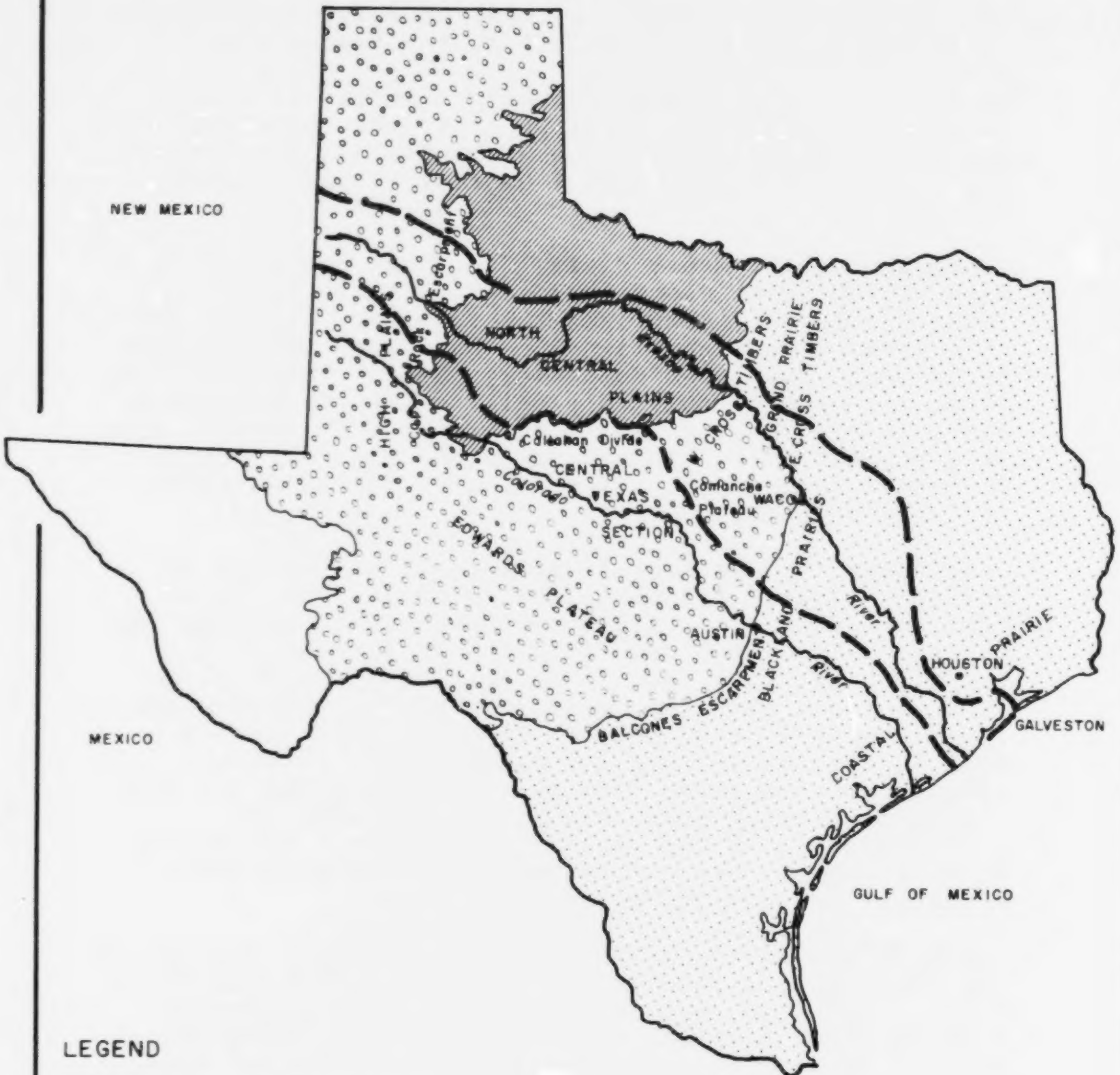
The study area is topographically a series of plains characteristic of the great physiographic provinces of the United States called the Great Plains, the Central Lowlands and the (West) Gulf Coastal Plains (Figure IV-2).

A section of the Great Plains Provinces known as the High Plains, with elevations from 2,500 to 5,000 feet (mean sea level), comprises the first and highest level of plains. The High Plains, extending to the Cap Rock Escarpment, is almost completely without erosional features interrupted only by scattered shallow undrained depressions, ranging from a few feet to 50 feet or more in depth and a few hundred feet to a mile or more in diameter; sand dunes; a few saline water table lakes and shallow water courses.

Just below the Cap Rock Escarpment is an expanse of rolling, lightly timbered country called the "North Central Plains", a section of the Central Lowlands Province. This area slopes from the escarpment at a elevation of 2,500 feet (mean sea level) to an elevation of about 800 feet (mean sea level). Erosion has left largely a great body of clay and shale with some weak sandstones forming low escarpments. However, erosion in some areas left massive limestones and sandstones from which have formed some features not characteristic of the general topography. The Brazos River is deeply entrenched in limestones with steep tributary canyons and mesas.

South of the North Central Plains is another section of the Great Plains Province called the Central Texas Section. Limestone once formed a continuous, seaward-sloping cover over all of this area. The limestone is heavily faulted along a line through Austin and Waco. Between the Brazos and Colorado Rivers the Central Texas Section is a eastward sloping plateau called the Comanche Plateau. A belt along the Brazos-Colorado Basin divide where the limestone has survived as a series of mesas is known as the Callahan Divide. The Callahan Divide marks the southern extent of the Central Lowland Province in Texas.

The Coastal Plain in the study area is a segment of the Gulf Coastal Plain that extends from Florida to Mexico.


NEW MEXICO
MEXICO
GULF OF MEXICO
Escarpment
HIGH PLAINS
Cap Rock
NORTH CENTRAL PLAINS
Callahan Divide
CENTRAL TEXAS SECTION
Colorado
Comanche Plateau
WACO
W. CROSS TIMBERS
GRAND PRAIRIE
E. CROSS TIMBERS
EDWARDS PLATEAU
AUSTIN
BALCONES ESCARPMENT
BLACKLAND PRAIRIES
River
River
COASTAL PRAIRIE
HOUSTON
GALVESTON

LEGEND

- ⚬ GREAT PLAINS PROVINCE
- ▨ CENTRAL LOWLAND PROVINCE (Osage Section)
- ░ COASTAL PLAIN PROVINCE

Adapted from Nevin M. Fenneman, Physiography of the Eastern United States and Physiography of the Western United States

SOURCE: THE REPORT OF THE U.S. STUDY COMMISSION-TEXAS PART II RESOURCES AND PROBLEMS

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN — TEXAS

PHYSIOGRAPHY

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE IV-2

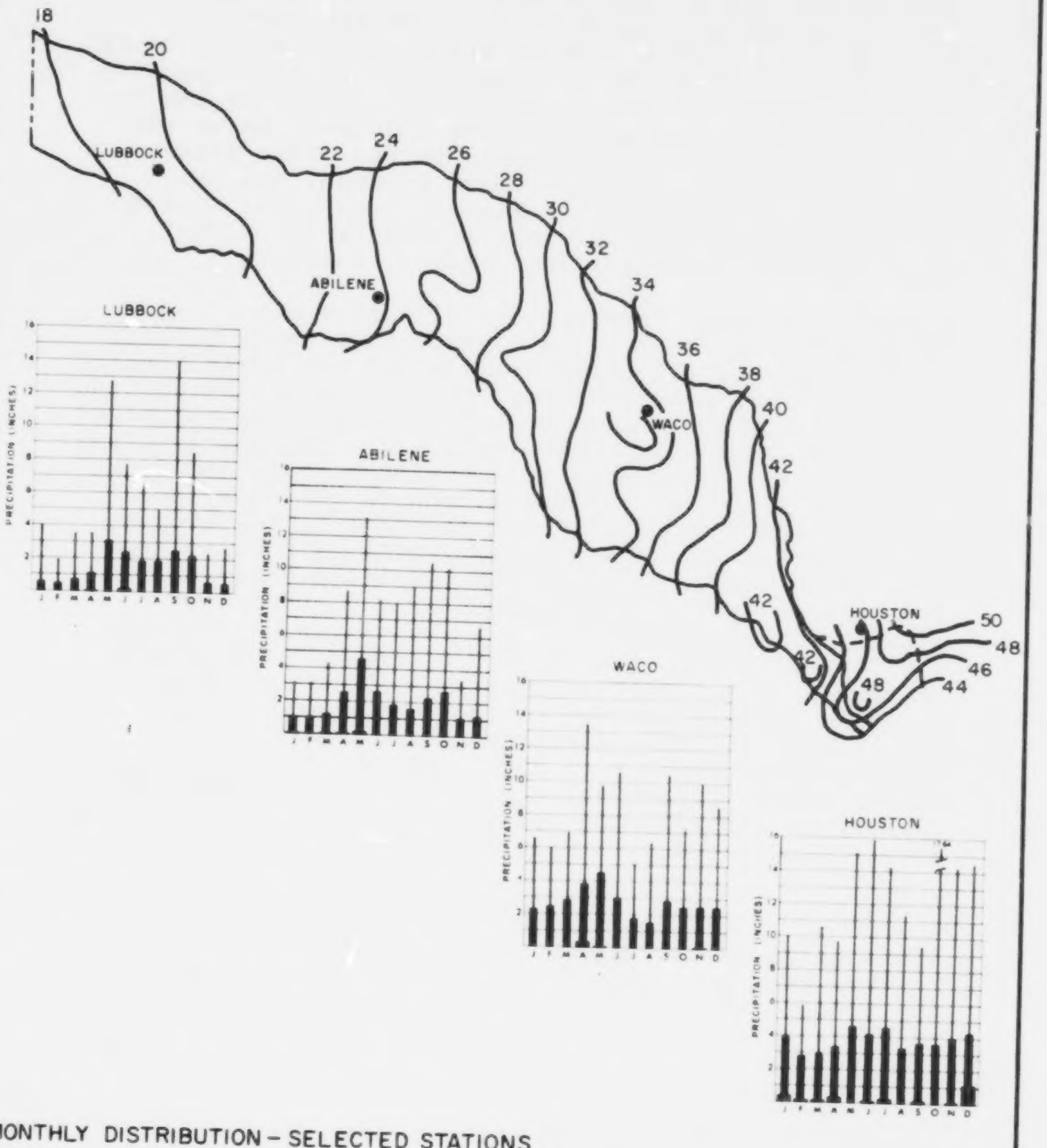
The coastal plains extend from the coast to the Balcones Escarpment (Figure IV-2). The Balcones Escarpment, a broken line of hills, marks the Balcones fault zone. Along the escarpment, where the elevation averages about 500 feet, there is a complex margin of transittional topography. There are three major subdivisions of the Coastal Plains in the study area: the Grand Prairie, the Blackland Prairies and the Coastal Prairie. Narrow strips of remarkable continuity which mark sandy outcrops called East and West Cross Timbers are significnat border features.

A gently rolling, forested belt, nowhere more than 10 miles wide, the West Cross Timbers is a sandy outcrop which separates the Grand Prairie and the North Central Plains. Lying generally North of the Brazos River, the Grand Prairie is an area underlain largely by resistant limestone which dips gently gulfward. The nearly level plains of the Grand Prairie are broken occasionally by the steep slopes of stream valleys in the limestone. Bounding the Grand Prairie on the East is the eroded, wooded East Cross Timbers area, which is another predominately sandy outcrop. The Blackland Prairies is typically a stiff, calcareous clay. The surface usually is gently rolling, with occasional flatlands. The Coastal Prairie is largely a deep accumulation of sediments. This belt of coastal lowland is the most recently emerged portion of the continental shelf. Quite level for some distance inland, the Coastal Prairie rises rapidly to about 100 to 175 feet along its inland edge. Except for the steep-sided channels of transverse streams, the Coastal Prairie is a clay plain almost unrelieved by erosional features.

Climate

The climate of the study area is typically humid in the eastern part and semiarid in the western part while in the midsection alternation between humid and dry conditions is typical. The variation in mean annual precipitation is shown on Figure IV-3 ranging from about 18 to 48 inches.

The Gulf of Mexico is the principal moisture source. Warm winds moving inland release moisture as they cool. Topography is of prime importance. Rises in elevation force the air upward where the atmospheric pressure is lower. The air expands under the lower pressure and is cooled. Two abrupt changes in topography are present


18
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44
46
48
48
50
LUBBOCK
ABILENE
WACO
HOUSTON
PRECIPITATION (INCHES)
J F M A M J J A S O N D

MONTHLY DISTRIBUTION – SELECTED STATIONS

Minimum, mean, and maximum monthly precipitation amounts are shown by wide, medium, and narrow bars respectively. Absence of a wide bar indicates the minimum was zero or a trace.

SOURCE: THE REPORT OF THE U.S. STUDY COMMISSION – TEXAS PART II RESOURCES AND PROBLEMS

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

MEAN ANNUAL PRECIPITATION
(Inches) 1919 – 1959

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE IV-3

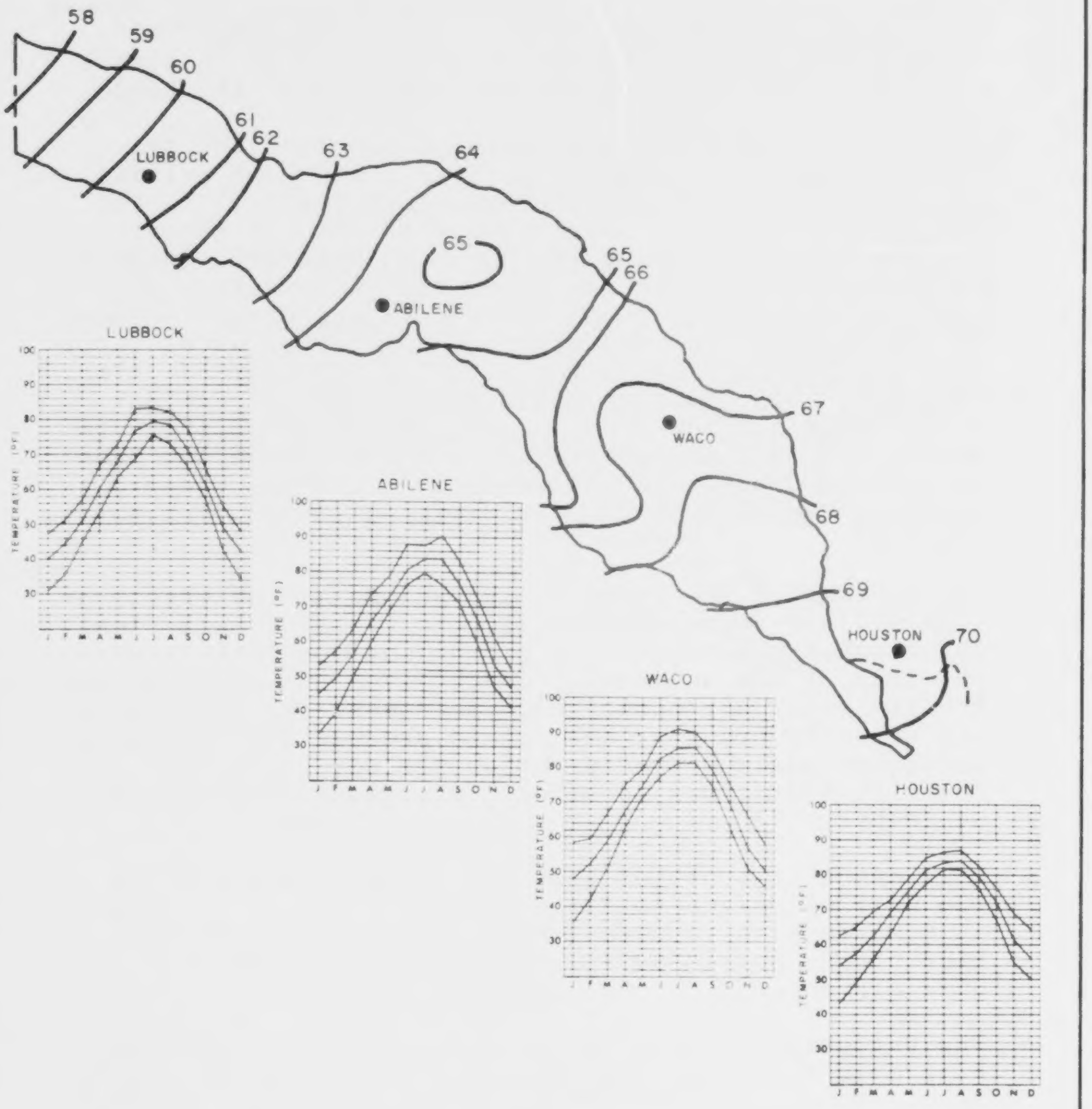
in the Brazos Basin, the Balcones Escarpment and the Cap Rock Escarpment (Figure IV-2). These topographical changes cause early release of moisture with resultant scarsity of moisture in the western part of the basin.

Monthly distributions are included for selected stations to show the rainfall pattern. Two peak rainfall periods are evident with the greatest rainfall during the April, May, June (spring) period and the second largest rainfall during the August, September, October (autumn) period. "In May, the winds have intermittently prevailed from the south for long enough periods of time to have carried great quantities of water vapor from the Gulf of Mexico far into the interior of Texas. The last of the winter season of cold air migrations from Canada and the Great Basin, the first of the warm season air mass thunderstorms, and springtime low pressure troughs aloft in the westerly winds all contribute to causing considerable precipitation and the May maximum." 2/

"By September, the first of the autumn-winter season of cold air has begun occasionally to clash with the long established moisture laden prevailing southerly winds. The last of the summertime convective thunderstorms and the two upper air convergence phenomena, easterly waves and westerly troughs, all act to produce the secondary September maximum precipitation period. Also, the severest hurricanes to affect Texas have occurred in September." 2/

Mean annual amounts of snowfall range from a trace near the Gulf of Mexico to 5.5 inches at Lubbock. 1/ Snow is sometimes an important source of moisture on the high plains but is relatively unimportant for this purpose elsewhere.

The variation in mean annual temperature is shown on Figure IV-4 ranging from about 58 to 70 degrees Fahrenheit. Monthly distributions are included for selected stations to show the extremes. The freeze-free period (growing season) is approximately 200 days in the high plains near Lubbock and 290 days near the coast. 1/ Lake surface evaporation is shown on Figure IV-5.


58
59
60
61
62
63
64
65
65
66
67
68
69
70
LUBBOCK
ABILENE
WACO
HOUSTON
LUBBOCK
ABILENE
WACO
HOUSTON
TEMPERATURE (°F)
100
90
80
70
60
50
40
30
J F M A M J J A S O N D

MONTHLY DISTRIBUTION – SELECTED STATIONS

Highest, mean, and lowest monthly temperatures are shown.

SOURCE: THE REPORT OF THE U.S. STUDY COMMISSION – TEXAS PART II RESOURCES AND PROBLEMS.

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

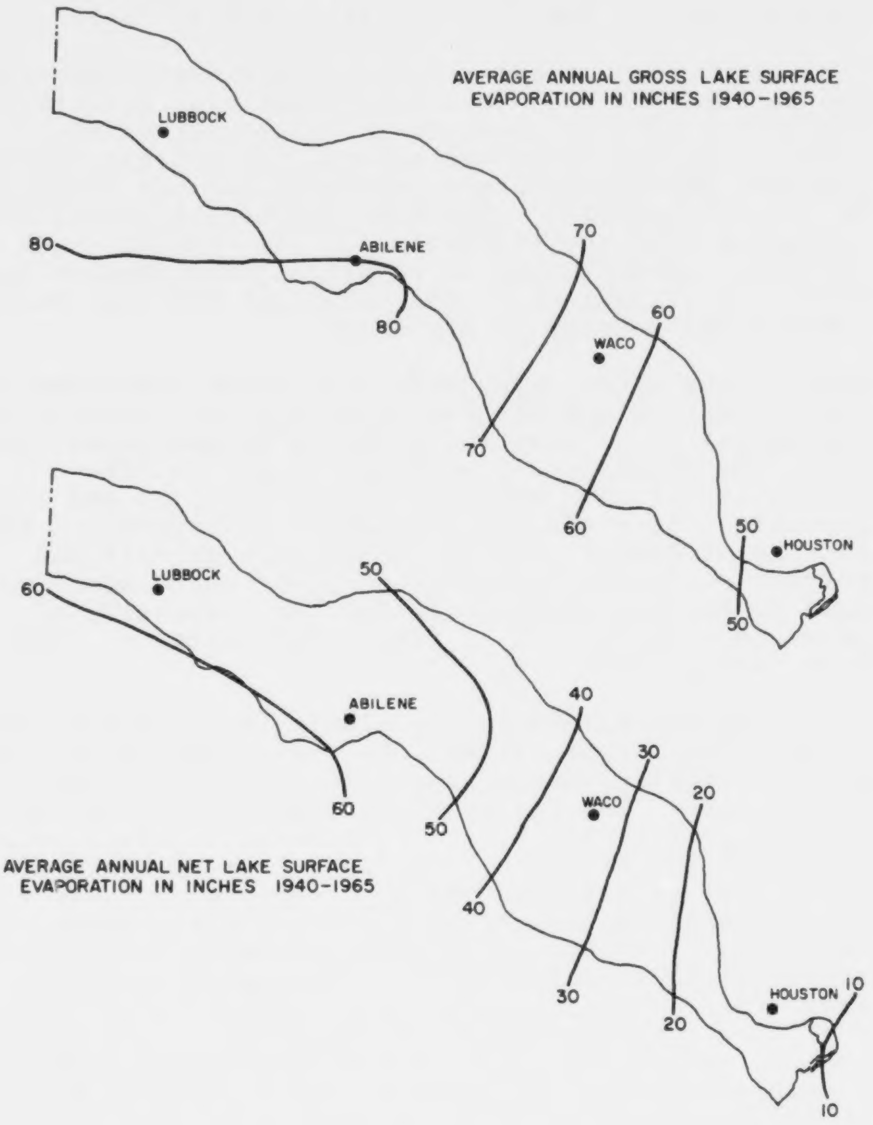
MEAN ANNUAL TEMPERATURES

(Degrees Fahrenheit) 1919 – 1957

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE IV – 4



AVERAGE ANNUAL GROSS LAKE SURFACE EVAPORATION IN INCHES 1940–1965

AVERAGE ANNUAL NET LAKE SURFACE EVAPORATION IN INCHES 1940–1965

LUBBOCK
ABILENE
WACO
HOUSTON
80
80
70
70
60
60
50
50
LUBBOCK
ABILENE
WACO
HOUSTON
60
60
50
50
40
40
30
30
20
20
10
10

SOURCE: TEXAS WATER DEVELOPMENT BOARD
REPORT 64 Oct. 1967

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

LAKE SURFACE EVAPORATION

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE IV-5

Principle Communities and Industries

Communities within the study area with populations greater than 10,000 in 1970 are listed in Table IV-1.

"The production of oil and gas is the most widespread and perhaps the most important industrial activity in the basin. Oil is produced in almost all of the counties in the basin and natural gas and gas liquids (natural gasoline, butane, and propane) are produced in several counties. The many supporting activities connected with the production of oil and gas, such as refining, distribution of supplies, distribution and servicing of equipment, and technical services further enhance the economy of the areas.

Some of the other industrial activities concerned with the production and processing of mineral products are the operation of sand and gravel pits and stone quarries, the mining and processing of gypsum, the production of clay and manufacture of brick and tile products, the production of cement materials and manufacture of cement, and the production of salt and sulphur. Lignite is mined in Milam County where it is used to produce electricity for the processing of aluminum ores shipped in from other states or imported from foreign countries.

The principal manufacturing plants in the basin are in or near the larger cities. However, other plants also process local products, especially those related to agriculture. The Cities of Waco and Temple in the eastern part of the basin in McLennan and Bell Counties, respectively, are important manufacturing centers, where some of the products produced include auto tires for national distribution, glass and glass containers, textiles, clothing, furniture, rock wool insultation, shoes, clay products, cement, cottonseed oil, food, and feed stuff. Lubbock, the largest city in the basin, is the third ranking inland cotton market in the world. The cottonseed oil mills in the vicinity of Lubbock have a combined production which is the largest of any city in the world.

Agriculture has contributed substantially to the economy of the basin; however, the development of groundwater for irrigation has greatly increased the production of

TABLE IV-1

COMMUNITIES WITH POPULATIONS GREATER THAN 10,000 IN 1970

Sub-Area a/	Community	Population 1960	Population 1970
1		341,635	344,167
	Lubbock	128,691	149,101
	Plainview	18,735	19,096
	Levelland	10,153	11,445
2		196,340	178,839
	Abilene	90,368	89,653
	Sweetwater	13,914	12,020
3		311,594	339,147
	Waco	97,808	95,808
	Cleburne	15,381	16,015
	Mineral Wells	11,053	18,411
4		237,794	279,270
	Kileen	23,377	35,507
	Temple	30,419	33,431
	Copperas Cove	4,567	10,818
5		171,408	172,942
	Bryan	27,542	33,719
	College Station	11,396	17,676
6		282,943	358,554
	Galveston b/	67,175	61,807
	Texas City b/	32,065	38,908
	LaMarque b/	13,969	16,131
	Lake Jackson b/	9,651	13,376
	Rosenberg	9,698	12,098
	Freeport	11,619	11,997
	League City b/	-	10,818
	Dickinson b/	4,715	10,776
	Alvin b/	5,643	10,671
1-6		1,541,714	1,672,919

---

a/ Values shown for sub-areas are full county populations for the counties partially or wholly within the sub-area.

b/ In Brazos-San Jacinto Coastal Basin.

agricultural products and improved the standard of living on farms in some parts of the basin. In 1958, about 2,653,000 acres were under irrigation in the Brazos Basin, about 98 percent being irrigated with groundwater."

"In the 1930's and 1940's, cattle raising and dryland farming gave way to large-scale irrigation farming in the High Plains. Irrigation increased in many areas in the basin during the drought of the early 1950's, and as of 1962 the part of the Brazos River Basin in the High Plains, along with other parts of the High Plains, constituted one of the largest intensively cultivated regions of the State. As a result of the large-scale development of irrigation in the High Plains, the population, both rural and urban, increased. The towns and cities of the irrigated areas became distribution centers for large quantities of equipment and supplies necessary in the development and operation of irrigated farms.

As a result of the drought of the 1950's, irrigation was developed in other parts of the basin wherever groundwater was available, notably in the Osage Plains section. Here again, the value of the agricultural production increased and the standard of living improved.

In the eastern part of the basin where dryland farming is generally successful, irrigation is used chiefly as a supplement to the usually adequate rainfall. Cotton, grain sorghums, and wheat are the principal crops in the western part of the area; in the eastern part, cotton and grain sorghums are the main crops and vegetables and alfalfa are minor crops.

The raising of beef cattle is an important part of the agricultural economy in the Brazos River Basin; however, the areas of greatest beef cattle production have shifted. In the early years, the High Plains section and parts of the Osage Plains section were important cattle raising areas. Although cattle raising is still important to the economy of these sections, the number of cattle on farms and ranches has decreased, whereas the number of cattle on farms and ranches in the area along the inner Coastal Plain has increased.

There are several colleges in the Brazos River Basin, such as Wayland College at Plainview; Texas Technological College and Lubbock Christian College, both at Lubbock; Hardin Simmons, McMurry and Abilene Christian College at

Abilene; Baylor University at Waco; Southwestern University at Georgetown; and Texas A & M College at College Station." 3/

V. WATER RESOURCES OF THE STUDY AREA

Groundwater

General

Aquifers providing significant quantities of fresh to slightly saline water within the study area are termed "Primary" if they yield large quantities of water over relatively large areas and "Secondary" if they yield either large quantities of water over small areas or small quantities over large areas.

Primary aquifers underlying the study area (Figure V-1) are the Ogallala Formation, Quaternary Alluvium (Osage Plains), Trinity Group, Brazos River Alluvium, Carrizo Sand and Wilcox Formation undifferentiated and the Gulf Coast Aquifers (Catahoula Sandstone, Oakville Sandstone and Lagarto Clay, undifferentiated; Goliad Sand, Willis Sand and Lissie Formation, undifferentiated; Quaternary Alluvium). Secondary aquifers (Figure V-1) are the Edwards-Trinity (Rocks of Cretaceous Age in the High Plains), Woodbine, Santa Rosa (Dockum Group), Queen City Sandstone (Mount Selman Formation), Sparta Sand, and Edwards Limestone (Balcones Fault Zone).

Quantity

A perennial yield of about 505,000 acre-feet 4,5/ of fresh to slightly saline groundwater could be drawn from primary and secondary aquifers in the Brazos River Basin and the Brazos-San Jacinto Coastal Basin. There are many other minor water bearing formations that can provide small quantity perennial supplies for ranches, small communities and limited irrigation.

The amount of water withdrawn from the Ogallala Formation each year greatly exceeds the recharge, therefore, use from the ogallala is not included in the estimated perennial groundwater yield. In 1958, an estimated 67,000,000 acre-feet of economically recoverable water was stored in the aquifer. 3/ In 1959, the Ogallala Formation supplied about 2,200,000 acre-feet of the total 2,400,000 acre-feet of groundwater used in the basin.

QUATERNARY ALLUVIUM
(OSAGE PLAINS)

Yield - 38,000 acre-ft/yr
TDS 600 - 2000 Cl 200 - 500 SO_4 200 - 400
Hardness 300 - 700 SiO_2 25 - 35
F 1 - 2 NO_3 40 - 70
Fe 0.02 - 0.05
Avg well yield - 280 - 1300 gpm

TRINITY GROUP

Yield - 21,000 acre-ft/yr
TDS 400 - 1000 Cl 20 - 200 SO_4 30 - 150
Hardness 10 - 300 SiO_2 10 - 30
F high (>1.0) in many areas
Fe high (>0.3) in many areas
Avg well yield - 200 - 1000 gpm

EDWARDS - TRINITY
(HIGH PLAINS)

Yield - unknown
TDS 1100 Cl 270 SO_4 240
Hardness 500 SiO_2 50
F 3.5
Avg well yield - unknown

WOODBINE

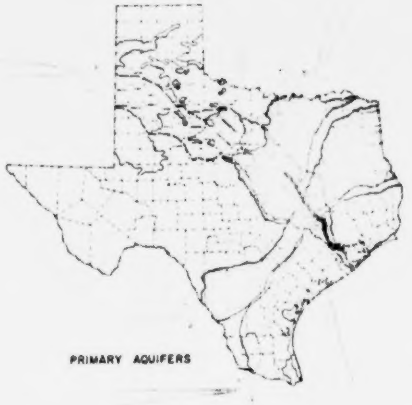
Yield - 1000 acre-ft/yr
TDS 600 - 2200 Cl 35 - 60 SO_4 150 - 500
Hardness 4 - 260 SiO_2 10 - 12
F C 2
Fe (>0.3) outcrop area
Avg well yield - 20 - 100 gpm

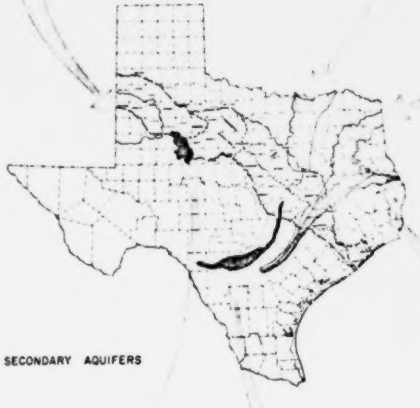
OGALLALA

Yield - Recharge is insignificant compared to pumpage
TDS 500 - 700 Cl 20 - 50 SO_4 30 - 100
Hardness 200 - 300 SiO_2 30 - 60
F 2 - 4
Fe 0.02 - 0.08
Avg well yield - 500 - 1000 gpm

CARRIZO - WILCOX

Yield - 100,000 acre-ft/yr
TDS 300 - 700 Cl 50 - 70 SO_4 2 - 30
Hardness 8 - 150 SiO_2 18 - 25
F 0.1 - 0.5
Fe high (>0.3) some areas
Avg well yield - 300 - 3000 gpm


PRIMARY AQUIFERS


SECONDARY AQUIFERS

QUEEN CITY

Yield - unknown
TDS 300 - 1000 Cl 75 SO_4 7
Hardness 50 - 150
F 1.6
Fe (>0.3) outcrop area
Avg well yield - 200 - 400 gpm

SPARTA

Yield - 10,000 acre-ft/yr
TDS 200 - 600 Cl 10 - 20 SO_4 5 - 20
Hardness 6 SiO_2 20 - 30
F 0.2 - 0.5
Fe (>0.3) outcrop area
Avg well yield - 300 - 500 gpm

GULF COAST AQUIFERS

Yield - 275,000 acre-ft/yr
TDS 300 - 900 Cl 40 - 100 SO_4 2 - 60
Hardness 100 - 150 SiO_2 15 - 20
F 0.2 - 0.5
Fe 0.05 - 0.3
Avg well yield - 1500 - 3400 gpm

BRAZOS RIVER ALLUVIUM

Yield - 51,000 acre-ft/yr
TDS 400 - 1000 Cl 100 - 200 SO_4 40 - 100
Hardness 200 - 1600 SiO_2 15 - 20
F 0.1 - 0.5 Boron 0.14 - 1.8
Avg well yield - 500 - 1350 gpm

SANTA ROSA

Yield - 3,400 acre-ft/yr
TDS 300 - 500 Cl 20 - 40 SO_4 30 - 70
Hardness 200 - 300 SiO_2 15 - 25
F 0.3 - 1.7
Avg well yield - 50 - 100 gpm

EDWARDS

Yield - 5000 acre-ft/yr
TDS 400 - 500 Cl 15 - 35 SO 35 - 40
Hardness 350 - 400 SiO 10
F 0.0 - 0.2
Fe 0.02 - 0.09
Avg well yield - 1000 - 2000 gpm

24

NOTE:
1. Yield is estimated yield for portion of aquifers underlying Brazos River Basin and the coastal area outlined
2. Yield shown for Gulf Coast Aquifers includes that portion of the Brazos River Alluvium below (south) of the Carrizo-Wilcox Aquifers
3. Ground water quality is highly variable. Mineral concentrations shown are representative values only in milligrams per liter.

SOURCE TEXAS WATER COMMISSION
BULLETIN 6310
DECEMBER 1963
THE TEXAS WATER PLAN
SUMMARY
NOVEMBER 1969

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN - TEXAS

GROUND WATER SUPPLY

ENVIRONMENTAL PROTECTION AGENCY
REGION VI DALLAS TEXAS

FIGURE V-1

A

QUATERNARY ALLUVIUM
(OSAGE PLAINS)

Yield - 38,000 acre-ft/yr
TDS 600-2000 Cl 200-500 SO_4 200-400
Hardness 300-700 SiO_2 25-35
F 1-2 NO_3 40-70
Fe 0.02-0.05
Avg well yield - 280-1300 gpm

TRINITY GROUP

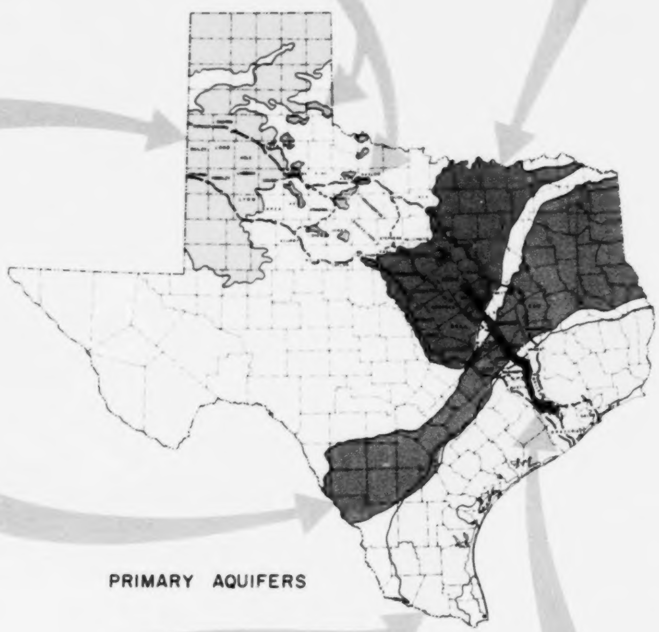
Yield - 21,000 acre-ft/yr
TDS 400-1000 Cl 20-200 SO_4 30-150
Hardness 10-300 SiO_2 10-30
F high (> 1.0) in many areas
Fe high (> 0.3) in many areas
Avg well yield - 200-1000 gpm

EDW

Yield - un
TDS 1100
Hardness 50
F 3.5
Avg well yie

OGALLALA

Yield - Recharge is insignificant compared to pumpage
TDS 500-700 Cl 20-50 SO_4 30-100
Hardness 200-300 SiO_2 30-60
F 2-4
Fe 0.02-0.08
Avg well yield - 500-1000 gpm



CARRIZO-WILCOX

Yield - 100,000 acre-ft/yr
TDS 300-700 Cl 50-70 SO_4 2-30
Hardness 8-150 SiO_2 18-25
F 0.1-0.5
Fe high (> 0.3) some areas
Avg well yield - 300-3000 gpm

PRIMARY AQUIFERS

SECONDARY

GULF COAST AQUIFERS

Yield - 275,000 acre-ft/yr
TDS 300-500 Cl 40-100 SO_4 2-50
Hardness 100-150 SiO_2 15-20
F 0.2-0.5
Fe 0.05-0.3
Avg well yield - 1500-3400 gpm

BRAZOS RIVER ALLUVIUM

Yield - 51,000 acre-ft/yr
TDS 400-1000 Cl 100-200 SO_4 40-100
Hardness 200-1600 SiO_2 15-20
F 0.1-0.5 Boron 0.14-1.8
Avg well yield - 500-1350 gpm

Yield - 3,400
TDS 300-50
Hardness 200-
F 0.3-1.7
Avg well yield

NOTE

SOURCE: TEXAS WATER COMMISSION
BULLETIN 6310
DECEMBER 1963

THE TEXAS WATER PLAN
SUMMARY
NOVEMBER 1968

B

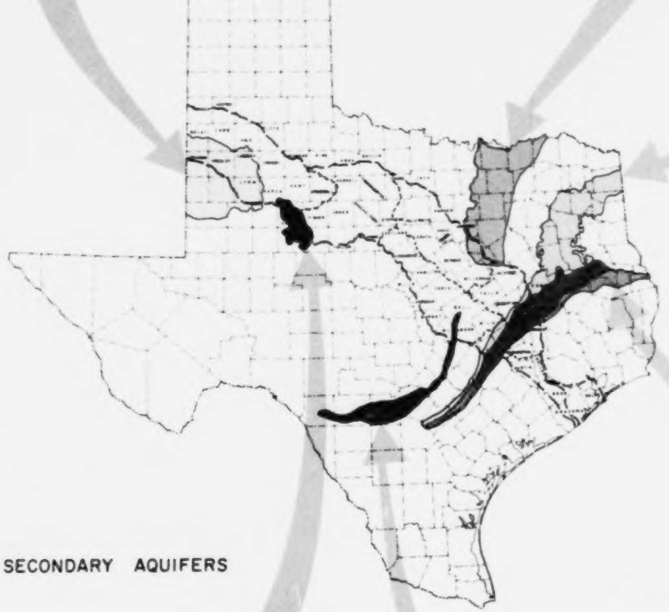
SO_4 30-150
10-30

EDWARDS – TRINITY
(HIGH PLAINS)

Yield – unknown
TDS 1100 Cl 270 SO_4 240
Hardness 500 SiO_2 50
F 3 5
Avg well yield – unknown

WOODBINE

Yield – 1000 acre-ft/yr
TDS 600-2200 Cl 35-60 SO_4 150-500
Hardness 4-260 SiO_2 10-12
F 0 2
Fe (> 0 3) outcrop area
Avg well yield – 20-100 gpm



QUEEN CITY

Yield – unknown
TDS 300-1000 Cl 75 SO_4 7
Hardness 50-150
F 1 6
Fe (> 0 3) outcrop area
Avg well yield – 200-400 gpm

SPARTA

Yield – 10,000 acre-ft/yr
TDS 200-600 Cl 10-20 SO_4 5-20
Hardness 6 SiO_2 20-30
F 0 2 - 0 5
Fe (> 0 3) outcrop area
Avg well yield – 300-500 gpm

SECONDARY AQUIFERS

LUVIUM

SO_4 40-100
-20
gpm

SANTA ROSA

Yield – 3,400 acre-ft/yr
TDS 300-500 Cl 20-40 SO_4 30-70
Hardness 200-300 SiO_2 15-25
F 0 3 - 1 7
Avg well yield – 50-100 gpm

EDWARDS

Yield – 5000 acre-ft/yr
TDS 400-500 Cl 15-35 SO 35-40
Hardness 350-400 SiO 10
F 0 0 - 0 2
Fe 0 02 - 0 05
Avg well yield – 1000-2000 gpm

NOTE:
1 Yield is estimated yield for portion of aquifers underlying Brazos River Basin and the coastal area outlined
2 Yield shown for Gulf Coast Aquifers includes that portion of the Brazos River Alluvium below (south) of the Carrizo-Wilcox Aquifers
3 Ground water quality is highly variable Mineral concentrations shown are representative values only in milligrams per liter.

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

GROUND WATER SUPPLY

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE V-1

Quality

Figure V-1 shows representative mineral concentrations of water supplied by primary and secondary aquifers in the Brazos River Basin. Quality analyses in Appendix I show the variability of quality in the aquifers. It can be seen that the mineral content of the groundwater, in many instances, exceeds maximum limits recommended in the U. S. Public Health Drinking Water Standards. 6/ It can also be seen that the water in many areas is very hard. The quality of water in each aquifer is discussed below:

Ogallala - Water from this aquifer typically is hard and has an objectionably high concentration of fluoride. Dissolved solids are normally above 500 mg/l but seldom exceed 800 mg/l. High silica concentrations exist universally.

Quaternary Alluvium (Osage Plains) - The mineral content of water from the alluvium is highly variable. Dissolved solids range from 300 to 4,000 mg/l but normally fall in the range from 100 to 2,000 mg/l. The water generally has objectionably high concentrations of fluoride and nitrates. High silica concentrations exist universally.

Trinity Group - Dissolved solids are usually above 400 mg/l but seldom exceed 1,000 mg/l. Normally, water from shallow wells is hard while deeper wells yield soft water high in sodium bicarbonate content. Objectionably high concentrations of fluoride and iron occur in many areas.

Gulf Coast Aquifers - Most of the water drawn from the aquifer is moderately hard to very hard, although soft water generally can be obtained by selectively screening deeper sands. However, the water from the deeper sands contains greater concentrations of bicarbonate than the water in the shallow sands. Dissolved solids concentrations are generally less than 500 mg/l and chlorides are less than 250 mg/l in the area above Brazoria County. In the northern half of Brazoria County dissolved solids generally range from 500 to 1,000 mg/l with chlorides less than 250 mg/l, while in the southern half of the county dissolved solids concentrations frequently exceed 1,000 mg/l and chloride exceed 250 mg/l.

Edwards-Trinity (High Plains) - Water from the aquifer is very hard and the dissolved solids, chloride, fluoride, and nitrate contents exceed the maximum limits recommended by the U. S. Public Health Service 6/ for drinking water.

Santa Rosa - Dissolved solids concentrations in water from the aquifer are generally less than 500 mg/1. The water is hard and has a moderately high silica content. The fluoride content is excessive for drinking water.

Edwards Limestone - The water is very hard. The concentrations of mineral constituents are generally below maximum levels recommended by the U. S. Public Health Service for drinking water. 6/

Queen City - The dissolved solids concentrations in water from the aquifer is usally above 300 mg/1 but seldom exceeds 1,000 mg/1. Generally the water is soft with a high sodium bicarbonate content. In some places, especially in and near the outcrop area, iron concentrations exceed 0.3 mg/1.

Carrizo-Wilcox - The dissolved solids concentrations in water from the aquifer is usually above 300 mg/1 but seldom exceeds 700 mg/1. Generally, the water is soft with a high sodium bicarbonate content. Iron concentrations frequently exceed 0.3 mg/1 in water pumped from the outcrop area.

Brazos River Alluvium 7/ - The mineral content of water from the river alluvium is highly variable. Radical changes often occur in short distances along the river. Generally, however, the water has a high bicarbonate content and is very hard. Dissolved solids concentrations range from about 400 mg/1 to more than 2,000 mg/1 but are usually within the range from 500 to 1,000 mg/1. The iron content exceeds 0.3 mg/1 in many areas. Chloride and sulfate concentrations exceed 250 mg/1 in southern areas throughout the alluvium but quite frequently exceed this level in Milam, Burleson, Robertson and Brazos counties.

Sparta Sand - The dissolved solids concentration in water from the aquifer is usually less than 600 mg/1. Generally the water is soft with a high sodium bicarbonate content. Iron concentrations frequently exceed 0.3 mg/1 in water pumped from the outcrop area.

Surface Water

General

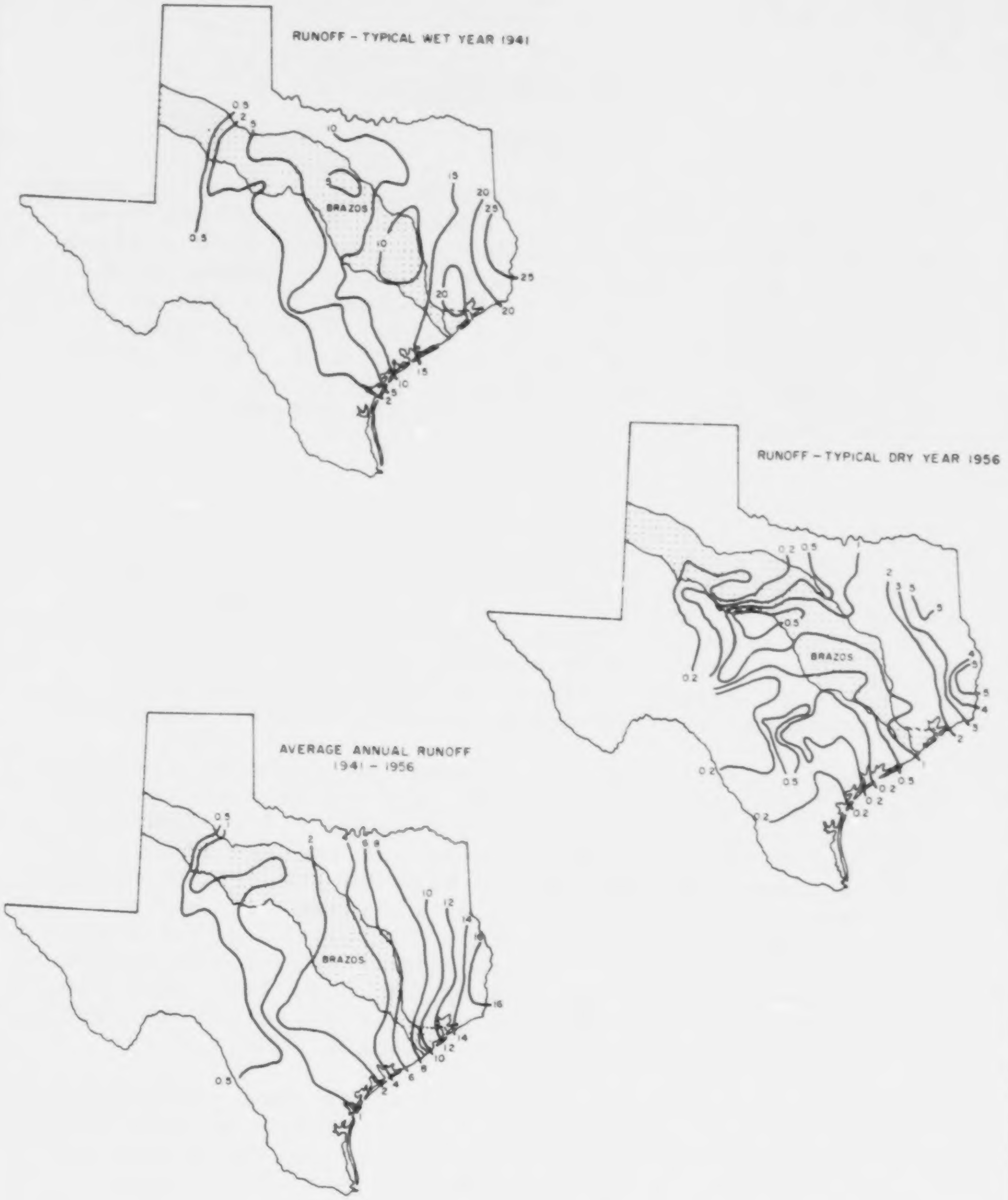
The study area extends almost 600 miles from the mouth of the Brazos River at the Gulf of Mexico where rainfall averages about 48 inches, northwest across Texas into New Mexico near the City of Clovis where rainfall averages only 18 inches. At the same time the average net lake surface evaporation varies from 10 inches near the mouth of the Brazos River to 60 inches near the headwaters. These climatic conditions sustain a broad ranged highly variable runoff pattern.

Quantity

Much of the Brazos River drainage basin (approximately 9,240 square miles) in New Mexico and in Texas west of the Caprock Escarpment, probably does not contribute flow to the lower basin. Below the Escarpment as far down the Basin as Possum Kingdom Reservoir, streamflow is very erratic. Many streams fluctuate from dry ditches to raging torrents in short time periods. More uniform flow patterns prevail further downstream.

Runoff generally increases from the upper to the lower basin but varies widely from year to year and between periods of wet and dry years (Figure V-2). "During the wet 7-year period 1940-46, the average annual runoff in acre-feet per square mile ranged from a maximum of 650 near the Gulf Coast to a minimum of 50 near the eastern edge of the Caprock. During the dry 7-year period 1950-56, the average annual runoff per square mile ranged from a maximum of 200 acre-feet near the Gulf Coast to less than 50 acre-feet west of a north-south line from Parker to Williamson County." 4/

Runoff is that part of precipitation that reaches surface drainage courses. Since the effect of man's control of the drainage system is reflected in the measurement of streamflow, a direct examination of historical streamflow records does not indicate an absolutely true measure of the quantity or pattern of natural runoff. However, an examination of historical records can be effectively used, without adjustment, to show general trends in runoff patterns. An analysis of streamflow records for the period water years 1941 to 1962 is presented on Figure V-3 to illustrate the general runoff



RUNOFF - TYPICAL WET YEAR 1941

RUNOFF - TYPICAL DRY YEAR 1956

AVERAGE ANNUAL RUNOFF
1941 - 1956

BRAZOS
0.5
2
5
10
15
20
25
BRAZOS
0.2
0.5
1
2
3
4
5
BRAZOS
0.5
1
2
4
6
8
10
12
14
16

SOURCE: THE REPORT OF THE U.S. STUDY
COMMISSION - TEXAS PART II
RESOURCES AND PROBLEMS

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN - TEXAS

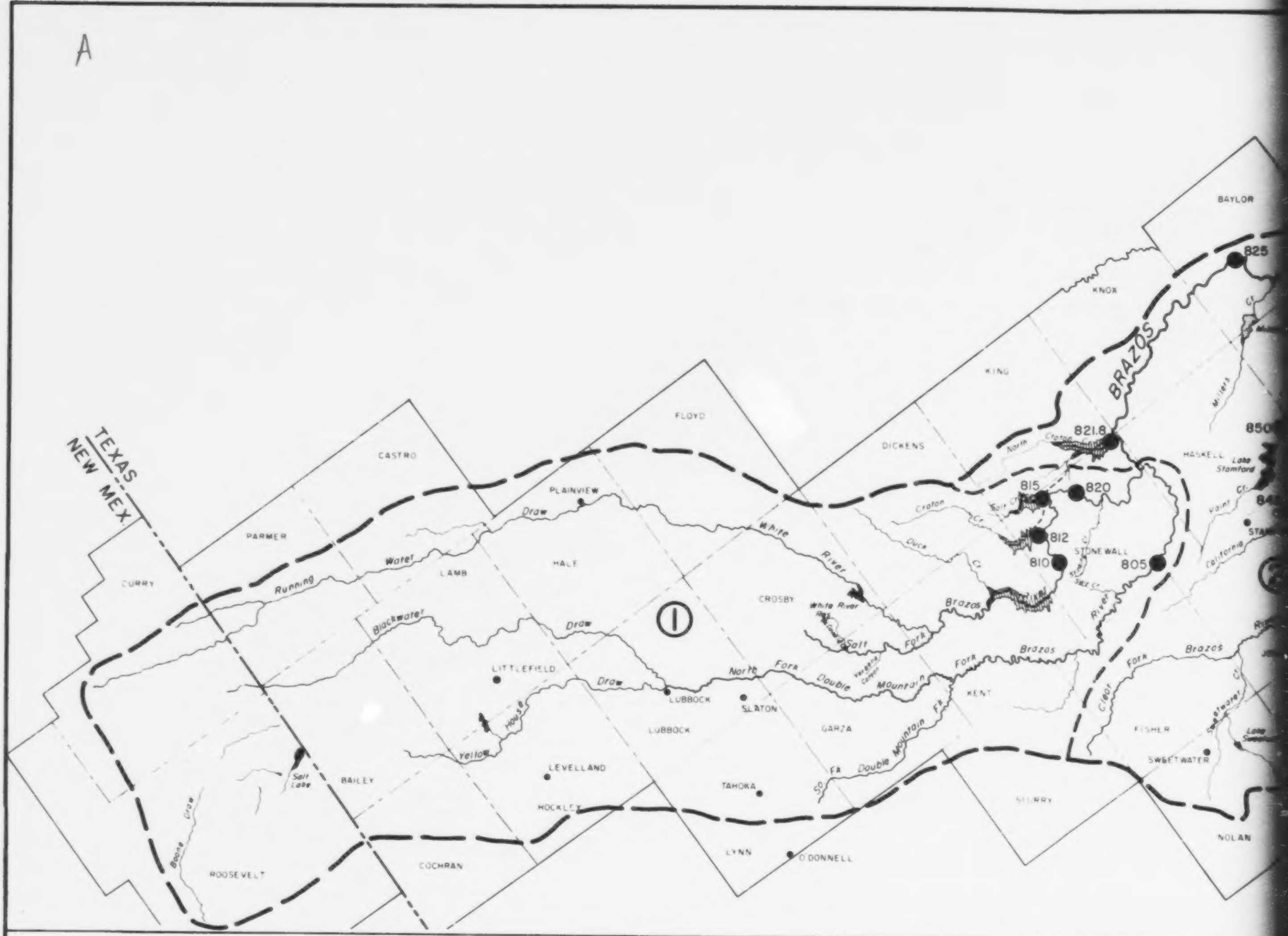
RUNOFF
(INCHES)

ENVIRONMENTAL PROTECTION AGENCY

REGION VI
DALLAS, TEXAS

FIGURE V-2

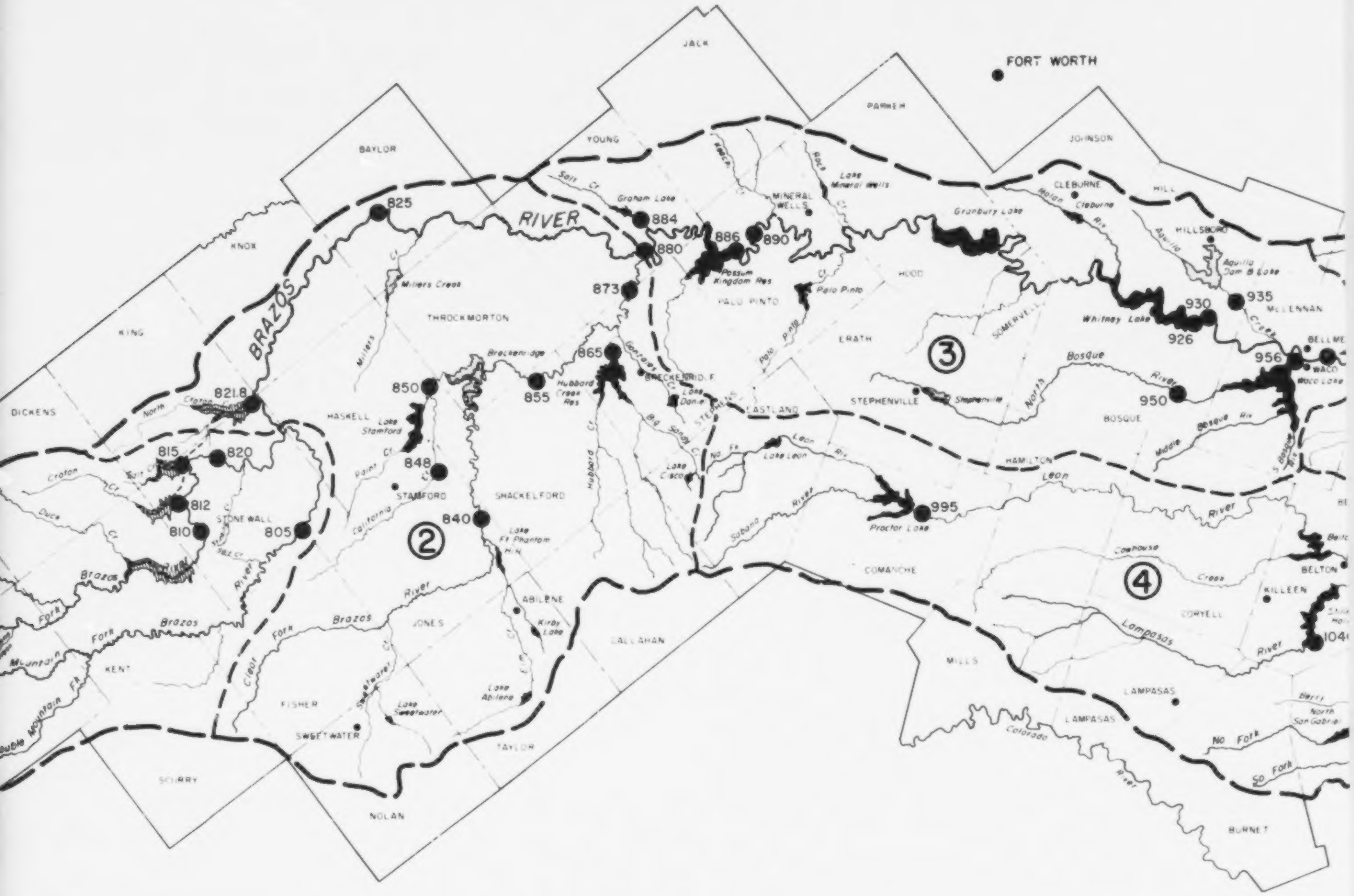
A


TEXAS
NEW MEX
CURRY
PARMER
CASTRO
FLOYD
PLAINVIEW
LAMB
HALE
CROSBY
DICKENS
KING
KNOX
BAYLOR
HASKELL
STONEWALL
KENT
GARZA
LUBBOCK
LYNN
SCURRY
FISHER
NOLAN
ROOSEVELT
BAILEY
COCHRAN
HOCKLEY
LITTLEFIELD
LEVELLAND
SLATON
TAHOKA
O'DONNELL
SWEETWATER
Running Water Draw
Blackwater Draw
Yellow House Draw
White River
White River Lake
Salt Fork Brazos
North Fork Double Mountain Fork Brazos
So. Fk. Double Mountain Fk.
Croton Cr.
Duck Cr.
Salt Cr.
Clear Fork Brazos
Millers Cr.
Paint Cr.
California Cr.
Lake Stamford
Salt Lake
Boone Draw
BRAZOS
①
825
821.8
815
820
812
810
805
850

USGS STATION	RECORDED FLOW (CFS) PERIOD WY 1941-62		SIMULATED FLOW (CFS) 1962 BASIN DEVELOPMENT WY 1941-62 RUNOFF		SIMULATED FLOW (CFS) 2020 BASIN DEVELOPMENT WY 1941-62 RUNOFF		U.S. GEOLOGICAL SURVEY 8/ 9/ ESTIMATES FOR WY 1957-66	FLOW WEIGHTED MEAN ANNUAL MINERAL CONTRIBUTION (TONS PER DAY)			SIMULATE 1962 BASI WY 1941-	
STATION NO.	MEAN ANNUAL FLOW (CFS)	STANDARD DEVIATION	MEAN ANNUAL FLOW (CFS)	STANDARD DEVIATION	MEAN ANNUAL FLOW (CFS)	STANDARD DEVIATION	MEAN ANNUAL FLOW (CFS)	CHLORIDE	SULFATE	TOTAL DISSOLVED SOLIDS	CHLORIDE	SU
805	189.3	424.3	188.8	425.1	245.0	429.7	189 a/	100	235	565	83.3	
810			70.9	163.5	3.9	9.1	78	215	85	520	213.1	
812			21.9	50.5	0	0	16 a/	75	80	240	70.6	
815			6.2	14.4	0	0	7.2 a/	530	35	920	525.4	
820	152.6	350.3	152.1	351.0	57.1	131.7	119 a/	830	250	1760	828.2	
821.8			10.5	23.2	0	0	25	50	70	190	50.7	
825	418.7	918.7	418.7	924.9	369.2	695.4	379 a/	940	600	2520	975.7	
840	96.3	329.7	98.5	320.5	131.7	324.9						
850			57.4	202.1	63.5	205.2					33.0	
855	224.4	654.2	213.0	719.0	187.5	700.5					80.9	
865			175.4	604.5	74.2	554.8	135 a/	29	5	86	44.5	
873			411.8	1404.0	285.1	1328.0	450 b/	165 b/	60 b/	480 b/	141.5	
880	1012.0	2394.0	1002.0	2363.0	794.0	2010.0					1128.8	
884			0.3	4.5	1.3	10.3					0.5	
886			1079.0	2517.0	879.6	2439.0	1200	1250	760	3440		
890	1114.0	2564.0	1119.0	2604.0	920.0	2530.0	1200 a/				1158.5	
926							1527 c/	1060 c/	672 c/	3200 c/		
930	1815.0	3507.0	1806.0	3140.0	1427.0	3127.0					1148.9	
935	117.8	220.1	117.4	218.9	94.9	178.0					5.7	
950	225.3	440.3	225.8	441.2	229.3	441.7						
956			458.9	968.1	362.4	895.9					13.2	
965	2546.0	4354.0	2531.0	4161.0	2176.0	4158.0						
995	157.8	374.9	157.8	375.6	109.6	350.0						
1025	725.5	1292.0	725.2	1475.0	722.6	1457.0						
1040	309.1	548.6	309.0	549.4	308.9	549.5						
1050	130.7	214.3	130.7	214.7	115.7	206.2						
1065	1802.0	2691.0	1806.0	2827.0	1560.0	2583.0					120.2	
1090	5381.0	7656.0	5367.0	7643.0	4776.0	7154.0					1321.0	
1100	282.1	479.5	281.7	480.4	230.4	414.1					31.4	
1105	414.8	751.0	413.6	749.1	416.1	749.4						
1110			682.4	1237.0	500.5	1011.0					167.3	
1140	7740.0	10240.0	7730.0	10790.0	6801.0	9695.0	5651 c/	1300 c/	946 c/	5600 c/	1554.6	

a/ Recorded Flow WY 1957-66
b/ Exclusive of Area above Hubbard Creek Reservoir
c/ WY 1949-64

B



FORT WORTH
JACK
PARKER
JOHNSON
HILL
BAYLOR
YOUNG
KNOX
KING
DICKENS
BRAZOS
RIVER
THROCKMORTON
HASKELL
STONEWALL
SHACKELFORD
PALO PINTO
HOOD
SOMERVELL
ERATH
EASTLAND
STEPHENVILLE
BOSQUE
HAMILTON
COMANCHE
MILLS
CORYELL
LAMPASAS
BURNET
CALLAHAN
JONES
TAYLOR
NOLAN
FISHER
SCURRY
KENT
McLENNAN
CLEBURNE
HILLSBORO
WACO
BELTON
KILLEEN
ABILENE
SWEETWATER
STAMFORD
MINERAL WELLS
825
884
880
886
890
873
865
855
850
848
840
821.8
815
820
812
810
805
930
935
926
956
950
995
Graham Lake
Possum Kingdom Res
Lake Mineral Wells
Granbury Lake
Whitney Lake
Aquilla Dam & Lake
Lake Stamford
Hubbard Creek Res
Breckenridge
Lake Cisco
Lake Leon
Proctor Lake
Lake Ft Phantom Hill
Kirby Lake
Lake Abilene
Lake Sweetwater
Palo Pinto
Waco Lake
Salt Cr
Millers Creek
Clear Fork
Brazos
Brazos River
Double Mountain Fk
Croton Cr
Duck Cr
Paint Cr
California Cr
Hubbard Cr
Big Sandy Cr
Sabana River
Leon River
Cowhouse Creek
Lampasas River
Colorado River
North Bosque River
Middle Bosque Riv
Nolan Riv
No Fork
So Fork
②
③
④

GEOLOGICAL SURVEY 8/ 9/			SIMULATED MEAN ANNUAL MINERAL CONTRIBUTION (TONS PER DAY)					
IMATES FOR WY 1957-66			1962 BASIN DEVELOPMENT WY 1941-62 RUNOFF			2020 BASIN DEVELOPMENT WY 1941-62 RUNOFF		
FLOW WEIGHTED MEAN ANNUAL INERAL CONTRIBUTION (TONS PER DAY)								
HLORIDE	SULFATE	TOTAL DISSOLVED SOLIDS	CHLORIDE	SULFATE	TOTAL DISSOLVED SOLIDS	CHLORIDE	SULFATE	TOTAL DISSOLVED SOLIDS
100	235	565	83.3	217.6	506.8	121.1	256.2	655.7
215	85	520	213.1	81.5	497.1	21.7	7.5	54.7
75	80	240	70.6	79.0	245.9	0	0	0
530	35	920	525.4	34.8	931.1	0	0	0
830	250	1760	828.2	240.0	1738.4	40.8	52.1	119.1
50	70	190	50.7	65.0	181.6	0	0	0
940	600	2520	975.7	546.5	2491.7	175.4	332.2	839.7
			33.0	56.3	122.4	39.6	76.1	142.5
			80.9	92.3	295.4	81.3	92.0	280.1
29	5	86	44.5	10.8	108.2	31.7	7.8	76.5
165 b/	60 b/	480 b/	141.5	105.1	443.3	129.2	101.8	396.3
			1128.8	675.1	3031.5	310.7	510.2	1333.6
			0.5	1.2	25.8	0.2	0.4	9.2
1250	760	3440	1158.5	731.3	3165.4	350.6	553.1	1488.3
1060 c/	672 c/	3200 c/	1148.9	736.6	3499.9	320.3	489.5	1646.5
			5.7	7.8	75.1	6.4	7.5	73.9
			13.2	19.6	118.2	13.4	17.9	107.1
			120.2	103.3	836.3	136.4	108.3	880.0
			1321.0	915.0	4861.0	583.5	732.9	3341.3
			31.4	65.4	245.4	33.0	68.4	256.7
			167.3	53.0	464.5	141.8	45.0	396.9
1300 c/	946 c/	5600 c/	1554.6	1124.4	6019.8	813.2	943.1	4519.5

LEGEND

820 ● U.S.(

RESE

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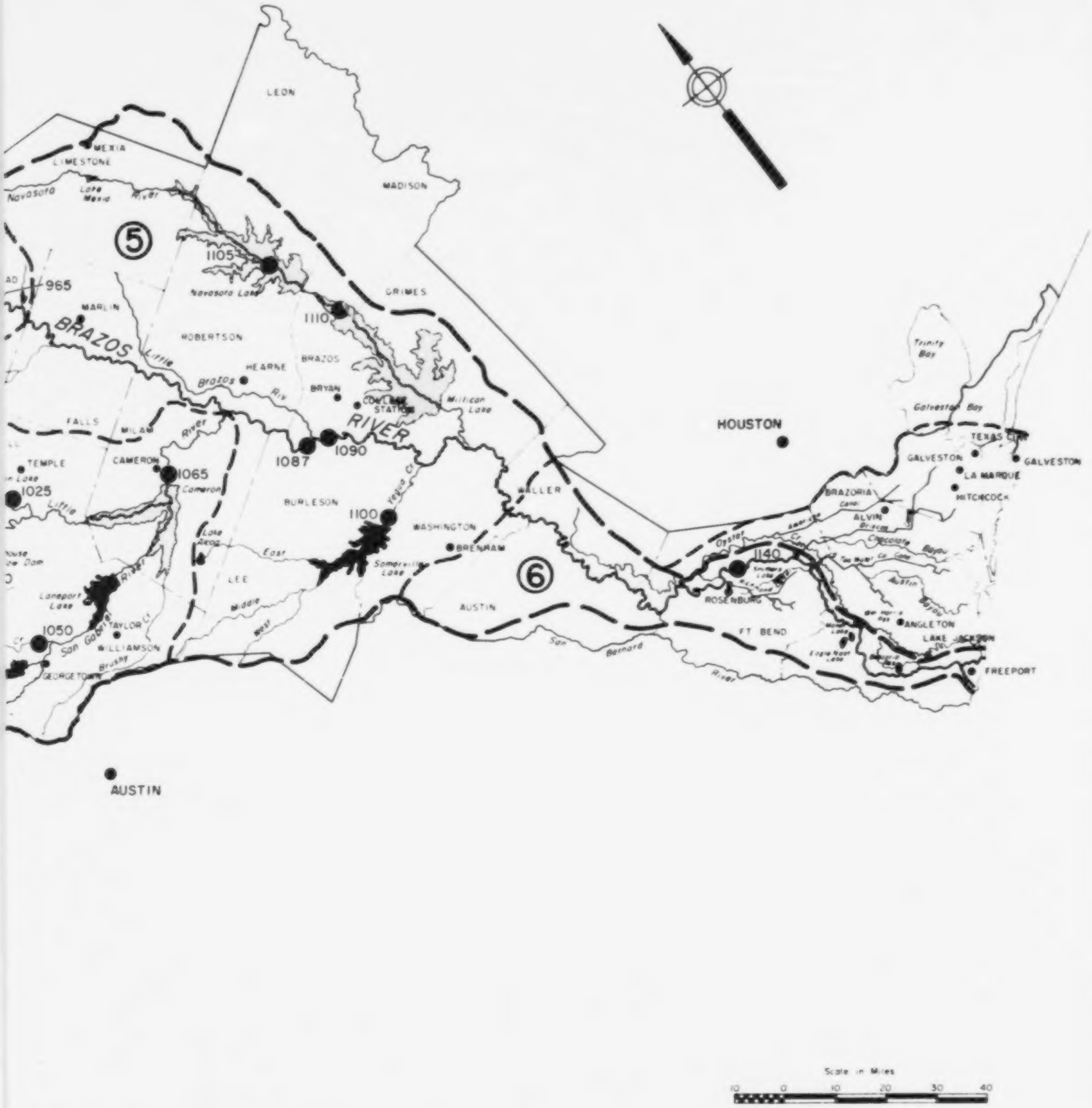
LEON
MADISON
MEXIA
LIMESTONE
Navasota
Lake Mexia
River
5
1105
Navasota Lake
1110
GRIMES
965
MARLIN
BRAZOS
ROBERTSON
Little
HEARNE
BRAZOS
Brazos
BRYAN
COLLEGE STATION
Millican Lake
FALLS
MILAM
River
RIVER
1087
1090
TEMPLE
CAMERON
1065
1025
Little
BURLESON
1100
Yegua Cr.
WASHINGTON
BRENHAM
Lake Bastrop
East
Somerville Lake
LEE
Middle
West
WALLER
6
AUSTIN
Laneport Lake
1050
San Gabriel
TAYLOR
WILLIAMSON
Brushy
GEORGETOWN
AUSTIN
HOUSTON
Trinity Bay
Galveston Bay
TEXAS CITY
GALVESTON
GALVESTON
LA MARQUE
HITCHCOCK
BRAZORIA
ALVIN
Oyster Cr.
1140
ROSENBURG
FT BEND
Chocolate Bayou
Austin Bayou
ANGLETON
LAKE JACKSON
San Bernard River
FREEPORT
Scale in Miles
10
0
10
20
30
40

S. STATION NUMBER

RVOIR EXISTING OR UNDER CONSTRUCTION

ERVOIR TO BE COMPLETED BY YEAR 2020

NITY CONTROL STRUCTURES

AREA NUMBERS

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

SURFACE WATER SUPPLY

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE V-3

distribution throughout the Brazos River Basin. Mathematical model simulated flows are also shown for comparison.

Flow in the Brazos River at Station 880 near South Bend, Young County averaged 1012 cfs (733,153 acre-feet per year) for the period of record. Runoff was collected from a drainage area of 21,600 square miles of which 9,240 is probably noncontributing. "The maximum year of runoff was 1957 with 2,461,000 acre-feet, and the minimum year was 1952 with 43,500 acre-feet." 4/

Flow in the Brazos River at Station 965, Waco, McLennan County averaged 2,546 cfs (1,844,475 acre-feet per year) for the period of record. "The maximum year of runoff was 1957 with 5,544,000 acre-feet, and the minimum year was 1952 with 403,600 acre-feet." 4/

Flow in the Brazos River at Station 1140, Richmond, Fort Bend County averaged 7,740 cfs (5,607,320 acre-feet per year) for the period of record. "The maximum year of runoff was 1941 with 16,120,000 acre-feet, and the minimum year was 1951 with 1,027,000 acre-feet." 4/

Table V-1 lists reservoirs greater than 5,000 acre-feet capacity that are expected to be in place by the year 2020. These reservoirs will provide a total safe yield of 1,175,300 acre-feet per year.

Quality

Chemical quality of surface water in the study area is highly variable. The quality not only differs from stream to stream but it also changes along the course of the streams and fluctuates at any point over a period of time. Therefore, it is necessary to describe quality by defining the percent of time the mineral concentration is within various ranges at a specific location. This analysis is, influenced, of course by the extent of available data. Many of the quality records for Brazos River Basin streams cover a very limited time frame. For prediction of future quality conditions, measured quality data has been extended by constructing a mathematical model of the Brazos Basin. The model and the quality predictions are described later in this report (Chapter VIII and Appendix II). This section of the report deals only with interpretation of available historical records.

TABLE V-1

RESERVOIRS

SUB-AREA	RESERVOIR	DATE COMPLETED	INCREMENTAL CAPACITIES 2020 (1000 ACRE-FEET)				CONTRIB-UTING AREA (SQ.MI.)	ESTIMATED YIELD b/ 2020 AC.FT./YR	OWNER
			FLOOD CONTROL	CONSER-VATION	DEAD	TOTAL			
			RESERVOIRS COMPLETED OR UNDER CONSTRUCTION						
1	Buffalo Springs	9-59	0	5.4	0	5.4	340	-	Lubbock Co Water Improvement Dist. No. 1
	White River	11-63	0	36.4	1.8	38.2	172	3,600	White River Municipal Water Dist.
2	Sweetwater	1930	0	8.2	3.7	11.9	104	1,700	City of Sweetwater
	Abilene	8-21	0	8.0	1.8	9.8	102	1,600	City of Abilene
	Kirby	1928	0	4.8	2.8	7.6	44	200	City of Abilene
	Fort Phantom Hill	10-38	0	67.0	7.3	74.3	478 d/	9,500	City of Abilene
	Stamford	6-53	0	47.6	12.4	60.0	360	600	City of Stamford
	Hubbard Lake	12-62	0	277.8	40.0	317.8	1107	14,900	West Central Texas Municipal Water Dist.
	Daniel	1948	0	3.0	7.0	10.0	87	-	City of Breckenridge
	Cisco	9-23	0	6.5	2.4	8.9	26	500	City of Cisco
3	Graham	1958	0	47.0	5.6	52.6	212	6,400	City of Graham
	Possum Kingdom Lake	3-41	0	188.1	536.3	724.4	13,310	86,000	Brazos River Authority
	Palo Pinto Creek	1964	0	39.5	4.6	44.1	471	11,200	Palo Pinto Co. Municipal Water Dist.
	Mineral Wells	9-20	0	5-0	3.4	8.4	63 d/	200	City of Mineral Wells
	Lake Granbury	1970	0	105.4	44.6	150.0	15,451	67.100	Brazos River Authority
	Pat Cleburne	1964	0	18.3	7.3	25.6	92	3,600	City of Cleburne
	Lake Whitney	12-51	1372.4	372.9	202.5	1947.8	16,930	122,300	U. S. Government
	Waco Lake	2-65	553.3	104.1	69.0	726.4	1,652	57,300	U. S. Government, City of Waco, Brazos R. Auth.
	Trading House Creek a/		0	37.8	0	37.8	39.1 d/	-	Texas Power and Light Co.
4	Proctor Lake	9-63	314.8	37.5	21.9	374.2	1,265	14,600	U. S. Government
	Leon	4-54	0	17.5	9.8	27.3	252	3,100	Eastland Co. Water Supply Dist.
	Belton Lake	3-54	640.0	398.5	59.1	1097.6	3,560	103,700	U. S. Government
	North San Gabriel Lake c/		87.6	29.2	14.0	130.8	246	11,500	U. S. Government
	Laneport c/		126.2	73.9	44.1	244.2	709	10,800	U. S. Government
	Stillhouse Hollow Lake	2-68	394.7	218.2	17.5	630.4	1,318	62,000	U. S. Government
	Lake Creek	5-52		9.5		9.5	17 d/	-	Texas Power and Light Co.
5	Mexia	6-61	0	0	10.0	10.0	-	0	Bistone Municipal Water Supply Dist.
	Camp Creek	11-48	0	7.7	0.9	8.6	40	2,600	Camp Creek Water Co.
	Alcoa	10-52	0	10.5	0	10.5	6 d/	-	Aluminum Co. of America
	Somerville Lake	1-67	337.7	143.9	25.9	507.5	1,006	35,600	U. S. Government
6	Smithers	10-57	0	18.0	0	18.0	24.2 d/	-	Houston Lighting and Power Co.
	William Harris a/	4-43	0	11.1	0.9	12.0	0 d/	-	Dow Chemical Co.
	Eagle Nest-Manor Lake	-	0	18.0	0	18.0	- d/	-	T. M. Smith et al
	Brazoria a/	5-54	0	21.3	0.7	22.0	-	-	Dow Chemical Co.
			RESERVOIRS PLANNED FOR CONSTRUCTION PRIOR TO 2020 e/						
2	Millers Creek		0	7.4	18.1	25.5		13,000	
	Breckenridge		0	550.0	67.0	617.0		54,900	
3	Stephenville		0	40.6	10.9	51.5		6,000	
	Aquilla Creek		111.5	59.7	28.1	199.3		15,200	
4	Cameron		0	1200.0	18.0	1218.0		95,400	
5	Navasota 2		550.7	1315.4	69.5	1935.6		231,600	
	Millican		359.0	1125.8	72.0	1556.8		128,600	

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a/ Off-channel reservoir.
b/ Does not include return flows. Yields were determined by the Texas Water Development Board.
c/ Under construction.
d/ Water pumped into reservoir from another drainage area.
e/ Breckenridge, Stephenville, Aquilla Creek and Millican are expected to be needed prior to 1979, Millers Creek by 1990, and Cameron and Navasota 2 by 2020

The United States Geological Survey has very adequately presented a summary of surface water quality conditions in a report 8/ for the Texas Water Development Board. Much of their discussion is "quoted" below. Table V-2 is their analysis of available records through 1964 to show the extent of past water-quality variations. Estimates of the quantity (tons per day) of salt contributed from various parts of the Brazos Basin are presented on Figure V-3.

The chemical quality of water of the Double Mountain Fork Brazos River near Aspermont is highly variable. The dissolved-solids content has ranged from less than 600 ppm to more than 7,000 ppm. During about 90 percent of the period of record, the dissolved-solids content equaled or exceeded 1,040 ppm; for about 10 percent of the time it equaled or exceeded 5,750 ppm. Similarly the sulfate, chloride, and hardness contents of the water are highly variable. During 80 percent of the time, sulfate concentrations ranged between 425 and 1,900 ppm, chloride concentrations ranged between 170 and 1,950 ppm, and hardness concentrations ranged between 460 and 2,470 ppm. The principal factor resulting in the variation of dissolved minerals was water discharge. The dissolved-solids content was usually highest during periods of low flow, when most of the flow consisted of groundwater inflow. The quality of water improved with increase in water discharge.

The dissolved-solids content of water of the Salt Fork Brazos River near Aspermont has ranged from about 1,000 ppm to more than 135,000 ppm. During about 50 percent of the period of record, the dissolved-solids content equaled or exceeded 33,900 ppm. (In comparison, the dissolved-solids content of ocean water averages about 35,000 ppm). The principal chemical constituents of the water also were highly variable. For example, during 80 percent of the time, the chloride content of the water ranged between 2,280 and 29,400 ppm. For about 50 percent of the time the chloride content equaled or exceeded 18,700 ppm. The dissolved-mineral content of the water was maximum during low flow when most of the flow was contributed by highly mineralized inflow from seeps and springs in the drainage area of Croton and Salt Croton Creeks. However, some medium and high flows also were very highly mineralized because of the solution of large quantities of salt that had been previously deposited in flats around salt springs and seeps and in stream channels.

TABLE V-2

SURFACE WATER QUALITY

Station (Figure V-2)	Stream and Location	Percent of Days Equaled or Exceeded				
		10	25	50	75	90
			Mean Daily Concentration (mg/l)			
805	Double Mountain Fork Brazos River near Aspermont					
	1949-51, 1957-64 water years:					
	Sulfate (SO_4)	1,900	1,720	1,480	870	425
	Chloride (Cl)	1,950	1,520	1,050	425	170
	Dissolved solids	5,750	4,850	3,770	2,000	1,040
	Hardness as $CaCO_3$	2,470	2,110	1,670	900	460
820	Salt Fork Brazos River near Aspermont					
	1949-51, 1957-64 water years:					
	Sulfate (SO_4)	3,000	2,920	2,600	1,720	780
	Chloride (Cl)	29,400	25,500	18,700	7,800	2,280
	Dissolved solids	51,500	45,000	33,900	15,000	4,900
	Hardness as $CaCO_3$	4,650	4,400	3,800	2,300	1,030
825	Brazos River at Seymour					
	1960-64 water years:					
	Sulfate (SO_4)	1,910	1,740	1,500	980	600
	Chloride (Cl)	6,200	5,200	3,750	1,650	720
	Dissolved solids	12,400	10,700	8,100	4,100	2,120
	Hardness as $CaCO_3$	2,300	2,100	1,750	1,060	630
848	California Creek near Stamford					
	1963-64 water years:					
	Sulfate (SO_4)	2,550	2,220	1,930	1,220	440
	Chloride (Cl)	2,600	2,200	1,800	1,100	380
	Dissolved solids	7,100	6,150	5,200	3,500	1,460
	Hardness as $CaCO_3$	2,600	2,300	2,000	1,400	640

TABLE V-2 (Continued)

SURFACE WATER QUALITY

Station (Figure V-2)	Stream and Location	Percent of Days Equaled or Exceeded 10	 25	 50	 75	 90
865	Hubbard Creek near Breckenridge	Mean Daily Concentration (mg/1)				
	1956-61 water years:					
	Sulfate (SO_4)	220	140	62	25	14
	Chloride (Cl)	930	580	240	92	48
	Dissolved solids	1,810	1,280	680	335	210
	Hardness as $CaCO_3$	740	550	320	175	115
	1963-64 water years:					
	Sulfate (SO_4)	340	72	18	13	11
	Chloride (Cl)	275	155	115	94	80
	Dissolved solids	1,000	470	330	278	250
	Hardness as $CaCO_3$	525	258	184	156	141
873	Clear Fork Brazos River at Eliasville					
	1962-64 water years:					
	Sulfate (SO_4)	620	400	205	64	30
	Chloride (Cl)	880	650	410	190	120
	Dissolved solids	2,210	1,600	1,000	500	365
	Hardness as $CaCO_3$	890	640	410	225	175
886	Brazos River below Possum Kingdom Dam, near Graford					
	1943-64 water years:					
	Sulfate (SO_4)	390	340	305	280	245
	Chloride (Cl)	650	565	500	450	380
	Dissolved solids	1,710	1,510	1,350	1,230	1,080
	Hardness as $CaCO_3$	515	465	425	395	370

TABLE V-2 (Continued)

SURFACE WATER QUALITY

Station (Figure V-2)	Stream and Location	Percent of Days Equaled or Exceeded				
		10	25	50	75	90
		Mean Daily Concentration (mg/l)				
926	Brazos River below Whitney Dam, near Whitney					
	1949-51 water years:					
	Sulfate (SO_4)	330	300	245	148	59
	Chloride (Cl)	510	470	400	250	102
	Dissolved solids	1,380	1,290	1,120	770	395
	Hardness as $CaCO_3$	450	425	375	275	165
	1953-64 water years:					
	Sulfate (SO_4)	280	245	200	155	113
	Chloride (Cl)	445	400	330	265	195
	Dissolved solids	1,230	1,120	960	795	635
	Hardness as $CaCO_3$	405	375	330	280	235
1040	Lampasas River at Youngsport					
	1962-64 water years:					
	Sulfate (SO_4)	28	23	20	15	12
	Chloride (Cl)	280	215	170	117	81
	Dissolved solids	660	550	468	370	298
	Hardness as $CaCO_3$	295	262	235	200	172
1065	Little River at Cameron					
	1961-64 water years:					
	Sulfate (SO_4)	59	50	42	36	30
	Chloride (Cl)	81	66	52	43	32
	Dissolved solids	447	385	325	289	242
	Hardness as $CaCO_3$	269	234	202	182	156

TABLE V-2 (Continued)

SURFACE WATER QUALITY

Station (Figure V-2)	Stream and Location	Percent of Days Equaled or Exceeded				
		10	25	50	75	90
		Mean Daily Concentration (mg/l)				
1087	Brazos River at State Highway 21, near Bryan					
	1962-64 water years:					
	Sulfate (SO_4)	195	172	143	107	71
	Chloride (Cl)	330	280	220	152	89
	Dissolved solids	960	850	720	560	400
	Hardness as $CaCO_3$	338	312	280	240	196
1100	Yegua Creek near Somerville					
	1962-64 water years:					
	Sulfate (SO_4)	275	212	125	66	41
	Chloride (Cl)	170	142	86	42	23
	Dissolved solids	800	635	390	220	143
	Hardness as $CaCO_3$	382	300	180	98	62
1110	Navasota River near Bryan					
	1959-64 water years:					
	Sulfate (SO_4)	49	43	37	30	24
	Chloride (Cl)	260	180	122	76	49
	Dissolved solids	570	427	320	225	165
	Hardness as $CaCO_3$	150	125	103	80	61

TABLE V-2 (Continued)

SURFACE WATER QUALITY

Station (Figure V-2)	Stream and Location	Percent of Days Equaled or Exceeded 10	25	50	75	90
		Mean Daily Concentration (mg/l)				
1140	Brazos River at Richmond					
	1943-51 water years:					
	Sulfate (SO_4)	196	149	86	53	36
	Chloride (Cl)	330	240	127	72	45
	Dissolved solids	960	750	465	315	235
	Hardness as $CaCO_3$	347	290	206	156	126
	1955-64 water years:					
	Sulfate (SO_4)	182	137	92	60	40
	Chloride (Cl)	300	219	136	82	51
	Dissolved solids	895	695	490	345	255
	Hardness as $CaCO_3$	330	275	215	166	134

NOTE:
For this frequency study, the dissolved-solids content of each daily sample was estimated from the specific conductance of the sample. These data for the period of record were used to prepare dissolved-solids duration curves. Curves of relation were plotted between these curves and concentrations of sulfate, chloride, and hardness. For each value of dissolved-solids in the table, corresponding concentrations of sulfate, chloride, and hardness were calculated. Care should be taken to consider the length of record and basin development when these values are used.

Source: Texas Water Development Board - Report 55

Water of the main stem Brazos River at the Seymour station during the 1960-64 period usually was slightly to very saline. Although the dissolved-solids content ranged from about 500 ppm to more than 20,000 ppm, about 50 percent of the time the dissolved-solids content equaled or exceeded 8,100 ppm. Because water at the Seymour station is a composite of water from both the Double Mountain and Salt Forks, the dissolved-solids content and the chemical composition depend largely upon the proportion of water contributed by each fork. When most of the water is contributed by the Salt Fork, the water usually ranges from moderately to very saline and chloride greatly predominates over sulfate. When most of the flow is contributed by the Double Mountain Fork, the water usually ranges from slightly to moderately saline; and although chloride usually is the predominant anion, the percentage of sulfate increases.

The water of the Clear Fork Brazos River usually is much superior in quality to that of either the Double Mountian Fork or the Salt Fork. During the 1962-64 water years, the dissolved-solids content of the Clear Fork Brazos River at Eliasville ranged from about 100 ppm to more than 3,200 ppm; but about 50 percent of the time the water contained less than 1,000 ppm. Water in California Creek, a tributary to the upper reach of the Clear Fork, generally was more mineralized than water of the Clear Fork at Eliasville. During the 1963-64 water years, the dissolved-solids content of water of California Creek near Stamford ranged from about 200 ppm, equaling or exceeding 5,200 ppm about 50 percent of the time. Although the relation between dissolved-solids content and water discharge was not precise, the dissolved-solids content in both California Creek and Clear Fork usually was minimum during high flows when most of the water consisted of direct runoff. However, the concentrations of principal dissolved constituents, especially chloride, varied markedly during some high-flow periods, apparently because of oil-field brine pollution. Because of this variation, the relation between dissolved-solids and individual chemical constituents was ill defined, and values for individual chemical constituents in Table V-2 are rough approximations.

Oil-field brine pollution also has resulted in marked variation of the quality of water of Hubbard Creek, the principal tributary to the lower reach of the Clear Fork Brazos River. During the 1956-61 period, before closure of Hubbard Creek Reservoir, the dissolved-solids content of Hubbard Creek near Breckenridge ranged from less than 100 ppm to more than 5,000 ppm. However, for about 50 percent of the time the dissolved-solids content equaled or exceeded 680 ppm. Although the chemical quality usually improved with increase in water discharge, the dissolved-solids content, especially the chloride content, was relatively variable at all discharge rates. Much of this variation probably resulted from oil-field brine pollution. Since the closure of Hubbard Creek Reservoir in 1962, most of the flow passing the Breckenridge station has consisted of runoff from the area downstream from the reservoir and seepage from the reservoir. During the 1963-64 water years, the dissolved-solids content of water at the Breckenridge station ranged from about 100 ppm to more than 2,000 ppm. However, about 50 percent of the time the water contained less than 330 ppm dissolved-solids.

A comparison of chemical-quality data for the Brazos River at the Possum Kingdom Dam station with those for upstream stations on both the main stem and tributaries show that storage of water in Possum Kingdom Reservoir has resulted in a decrease of quality-of-water variations. During the 1943-64 period, since the closure of Possum Kingdom Reservoir, the dissolved-solids content of water released or spilled from the reservoir has ranged from about 220 ppm to more than 3,800 ppm. However, for about 80 percent of the time the range has been from about 1,080 ppm to about 1,710 ppm. Similarly, for about 80 percent of the time the sulfate and chloride concentrations have ranged from 245 ppm to 390 ppm and from 380 to 650 ppm, respectively.

The collection of chemical-quality data from the Brazos River near Whitney pre-dates the closure of Whitney Reservoir. Therefore, chemical-quality frequency data for periods both before and after closure of Whitney Reservoir are given in Table V-2. During the 1949-51 water years, before the closure of the reservoir, the dissolved-solids content of the water ranged from less than 150 ppm to more than 1,500 ppm. During 50 percent of the time, the dissolved-solids content equaled or exceeded 1,120 ppm. During the same period, the dissolved-solids content of water released from Possum Kingdom Reservoir ranged from about 1,000 ppm to more than 1,600 ppm. Water from the drainage area between the two reservoirs is low in dissolved-solids. Much of the time before the closure of Whitney Reservoir, water at the Whitney station consisted largely of water released from Possum Kingdom Reservoir. During the 1953-64 period after the closure of Whitney Reservoir, the dissolved-solids content of water at the Whitney station ranged from less than 350 ppm to more than 1,400 ppm. About 50 percent of the time, the dissolved-solids content equaled or exceeded 960 ppm. During the same period, the dissolved-solids content of water released from Possum Kingdom Reservoir ranged from less than 300 ppm to more than 3,800 ppm, and for about 50 percent of the time equaled or exceeded 1,400 ppm. These data show that regulation of flow by Whitney Reservoir has resulted in an integration of the saline releases from Possum Kingdom Reservoir with water of better quality contributed by the intervening area. Mixing of these waters in Whitney Reservoir has resulted in more uniformity in the chemical quality of water at the Whitney station.

During the 1962-64 period of chemical-quality record for the Lampasas River at Youngsport, the dissolved-solids content of the water ranged from less than 150 ppm to more than 950 ppm. During about 40 percent of the time, the dissolved-solids content equaled or exceeded 500 ppm. Mills and Rawson (1965) have shown that although the base flow of most streams in the drainage area of the Lampasas River contains low concentrations of dissolved-solids, the base flow of Sulphur Creek is slightly saline. Therefore, the variation in chemical quality of the Lampasas River at Youngsport is attributed largely to differences in pattern of runoff. When most of the flow is contributed by Sulphur Creek, the dissolved-solids content is maximum. As the percentage of water contributed by other tributaries increases, the chemical quality of water of the Lampasas River improves.

Because water of the Little River at Cameron is a composite of the flow of the Leon, Lampasas, and San Gabriel Rivers, the dissolved-solids content and the chemical composition of the water depend largely upon the pattern of runoff from sub-basins. During the 1961-64 period of chemical-quality record, the dissolved-solids content of the Little River at Cameron ranged from less than 125 ppm to more than 675 ppm. Although the dissolved-solids content was maximum during low flow, it equaled or exceeded 500 ppm only about one percent of the time.

The quality of water of the main stem Brazos River near Bryan is relatively variable. During the 1962-64 water years, the dissolved-solids content ranged from less than 200 ppm to more than 1,200 ppm. About 50 percent of the time the dissolved-solids content equaled or exceeded 720 ppm. During the same period, the dissolved-solids content of water released from the upstream Whitney Reservoir equaled or exceeded 700 ppm for more than 99 percent of the time. These data indicate that the dissolved-solids content of water at the Bryan station is maximum when most of the flow consists of releases from Whitney Reservoir. As the proportion of water contributed by the intervening area between the reservoir and the Bryan station increases, the chemical quality of water improves.

The dissolved-solids content of water of Yegua Creek near Somerville during the 1962-64 water years ranged from less than 100 ppm to more than 950 ppm. About 40 percent of the time the dissolved-solids content equaled or exceeded 500 ppm. Although the chemical quality clearly improved with increase in water discharge, the dissolved-solids content and concentrations of individual constituents were variable at all discharge rates, but especially during medium and low flows. Although no chemical-quality data are available for tributaries, much of this variation at the Somerville station probably is due to differences in the pattern of runoff from sub-basins.

During the 1959-64 period, the dissolved-solids content of the Navasota River near Bryan ranged from less than 50 ppm to more than 2,200 ppm. However, the dissolved-solids equaled or exceeded 500 ppm for only about 15 percent of the time. The dissolved-solids content usually was maximum during low or medium flows. However, the relation between discharge and dissolved-solids content was ill defined. During some periods, both the dissolved-solids and chloride contents of the water increased erratically without a corresponding change in rate of flow. Much of this variation is attributed to oil-field brine pollution.

The collection of chemical-quality data from the Brazos River at Richmond pre-dates the construction of the upstream Whitney and Belton Reservoirs. Therefore, in Table V-2 chemical-quality frequency data for the Richmond station are shown for two periods--the period before closure of Whitney Reservoir and the period after closure of Belton Reservoir. During the 1943-51 period before closure of Whitney Reservoir, the dissolved-solids content of the Brazos River at Richmond ranged from less than 150 ppm to more than 1,400 ppm. About 50 percent of the time the dissolved-solids equaled or exceeded 500 ppm. During the same period, the dissolved-solids in water released from the upstream Possum Kingdom Reservoir ranged from about 800 ppm to more than 1,600 ppm. About 50 percent of the time the dissolved-solids content of water released from the reservoir equaled or exceeded 1,300 ppm. These data show that before the construction of Whitney Reservoir the quality of water at the Richmond station was relatively variable. The dissolved-solids content of the water was maximum when inflow from the intervening area between the Possum Kingdom and Whitney station was deficient. As the proportion of water contributed by the intervening area increased, the chemical quality of water at the Richmond station improved. For example, discharge records for the 1943-51 period indicate that during the January-June months, releases from Possum Kingdom Reservoir averaged less than 7 percent of the total flow at the Richmond station. For 50 percent of the days during the January-June period, the dissolved-solids content of water at the Richmond station was less than 360 ppm. During the July-December months, releases from Possum Kindgom Reservoir averaged more than 20 percent of the total flow at the Richmond station. For 50 percent of the days during the June-December period, water at the Richmond station contained more than 590 ppm dissolved-solids.

The dissolved-solids content of the Brazos River at Richmond during the 1955-64 period, since the closure of Whitney and Belton Reservoirs, has ranged from less than 150 ppm to more than 1,200 ppm. About 48 percent of the time the dissolved-solids content has equaled or exceeded 500 ppm. These data indicate that the regulation of flow by Whitney and Belton Reservoirs has not reduced appreciably the day-to-day variations of chemical quality of water at the Richmond station.

Return Flow

Multiple use of natural resources in effect increases the available supply. Where the geography is favorable waste water discharged by upstream users can be appropriated to satisfy downstream demands.

In the Brazos River Basin the geography and location of large population centers will allow only limited re-use of waste water. In most cases only two cycles of use are possible. Re-use of water is estimated to increase the available 2020 supply by 369,250 acre-feet per year.

Summary

Table V-3 is a summary of yields expected from planned development through the year 2020. The summary includes groundwater supplies in the Brazos-San Jacinto Coastal Basin; it does not include groundwater that will be mined from the Ogallala Formation or possible imports from East Texas Basins. Complete development of groundwater resources is assumed.

TABLE V-3

SURFACE WATER RESOURCES SUMMARY

Source	2020 Supply (acre-feet/year)
Import from Canadian Basin	47,300
Import from Colorado Basin	2,400
Reservoir Yield	1,175,300
Main Stem Diversion	85,000
Groundwater	505,000
Return Flow	369,250
	2,184,250

Utilization of the above listed supplies can be severely restricted by their high mineral concentrations. A large quantity of the water resources in the Brazos basin are presently damaged to such a degree that they cannot be used for municipal supplies. Satisfaction of water demands by using study area resources will be discussed later in this report.

VI. WATER REQUIREMENTS

General

Water requirement projections adopted for this study were prepared by the State of Texas Water Development Board for use in formulation of the Texas Water Plan. 10/ Projections independently prepared by the Environmental Protection Agency were not significally different.

Projection Criteria and Procedures

The following procedures and assumptions were used in projecting future requirements.

1. Smaller industries and commercial establishments presently obtaining or projected to obtain their water supplies from municipal systems were included in municipal requirements.

2. Large-scale industrial users - 10 thousand gallons per day or more, who purchase their supplies from municipal systems were separated into the industrial category.

3. It was assumed that necessary water supplies of suitable quality could be supplied at a cost similar to prices experienced in the basin over the recent historical period. Growth similar to that experienced historically and thus water demand would not be restricted by lack of adequate supplies. The type industrial development would be restricted by these assumptions, however, since water prices in some areas have historically discouraged development of large water using industries. Industrial development was projected in accordnace with what has been feasible in the past.

4. Municipal water requirements were calculated by multiplying projected per-capita use by projected population. Per-capita use data was developed from historic data collected by the Water Development Board for the years 1960-64 and by the State Health Department for the years 1956-62. Urban areas were assigned per-capita demands in accordance with their stage of growth as compared to similar area.

5. Industrial requirements were developed by comparing projected employment in basic industrial sectors with current and projected water requirements for those sectors. Projections of employment were based on area resource evaluations and the probable expansion of basic local industries.

6. The principal use of water for mining purposes is the recovery of petroleum by fluid injection. Water use projections were developed by evaluating the amount of petroleum potentially recoverable by water injection. It should be noted that either saline or fresh water can be used for secondary recovery and much of the requirement could be satisfied by use of saline water commonly produced with oil and gas or locally available.

7. The University of Texas made a detailed analysis of the future need for agricultural products in the nation and Texas probable share in providing these food and fiber requirements. Their studies show that economic incentives could exist by the year 2020 to support development of irrigated agriculture on 16.6 million acres of the 37 million acres of irrigable lands in Texas. This irrigation potential was then assigned to the most suitable areas in Texas. Water requirements were then calculated from historical water use data for local cropping patterns.

1960 Water Use

Table VI-1 shows 1960 water use for irrigation, mining and municipal supplies for each city in the study area with a 1960 population of more than 5,000 and "all other cities" with lesser populations considered as a group for each sub-area.

TABLE VI-1

1960 WATER USE a/
(Acre-Feet)

Sub-Area	City b/ and Type Use	Ground Water	Surface Water	Total
1	Municipal and Industrial			
	Levelland	3,300		3,300
	Littlefield	5,700		5,700
	Lubbock	23,000		23,000
	Plainview	3,400		3,400
	Slaton	800		800
	Other Cities	17,200		17,200
	TOTAL	53,400		53,400
	Irrigation	4,100,400	100	4,100,500
	Mining	14,900		14,900
	TOTAL SUB-AREA 1	4,168,700	100	4,168,800
2	Municipal and Industrial			
	Abilene		17,600	17,600
	Breckenridge		1,000	1,000
	Stamford		1,200	1,200
	Sweetwater		2,600	2,600
	Other Cities	5,900	5,900	11,800
	TOTAL	5,900	28,300	34,200
	Irrigation	116,700	6,000	122,700
	Mining	29,300		29,300
	TOTAL SUB-AREA 2	151,900	34,300	186,200

TABLE VI-1 (Continued)

Sub-Area	City b/ and Type Use	Ground Water	Surface Water	Total
3	Municipal and Industrial			
	Bellmead	400		400
	Cleburne	2,400		2,400
	Graham		2,900	2,900
	Hillsboro	1,200		1,200
	Mineral Wells		2,100	2,100
	Stephenville	1,200		1,200
	Waco	600	21,400	22,000
	Other Cities	11,100	3,800	14,900
	TOTAL	16,900	30,200	47,100
	Irrigation	1,200	8,500	9,700
	Mining	5,400		5,400
	TOTAL SUB-AREA 3	23,500	38,700	62,200
4	Municipal and Industrial			
	Belton	1,700		1,700
	Cameron		700	700
	Georgetown	2,500		2,500
	Killeen		3,500	3,500
	Lampasas		1,000	1,000
	Taylor	1,200		1,200
	Temple		4,800	4,800
	Other Cities	5,000	7,400	12,400
	TOTAL	10,400	17,400	27,800
	Irrigation	2,900	5,900	8,800
	Mining	1,000		1,000
	TOTAL SUB-AREA 4	14,300	23,300	37,600

TABLE VI-1 (Continued)

Sub-Area	City b/ and Type Use	Ground Water	Surface Water	Total
5	Municipal and Industrial			
	Brenham	1,000		1,000
	Bryan	5,200		5,200
	College Station	2,200		2,200
	Hearne	900		900
	Marlin		1,000	1,000
	Mexia		1,600	1,600
	Other Cities	5,000	1,400	6,400
	TOTAL	14,300	4,000	18,300
	Irrigation	71,400	24,700	96,100
	Mining	100		100
	TOTAL SUB-AREA 5	85,800	28,700	114,500
6	Municipal and Industrial			
	Alvin	1,800		1,800
	Angleton	700		700
	Freeport	12,400	50,500	62,900
	Galveston	12,200		12,200
	Hitchcock	400		400
	Houston (5 percent)	11,000	2,100	13,100
	Lake Jackson	1,100		1,100
	McMarque	1,500		1,500
	Rosenberg	9,800		9,800
	Texas City	16,500	19,700	36,200
	Other Cities	45,900		45,900
	TOTAL	113,300	72,300	185,600
	Irrigation	32,100	173,900	206,000
	Mining	2,200		2,200
	TOTAL SUB-AREA 6	147,600	246,200	393,800

TABLE VI-1 (Continued)

Sub-Area	City b/ and Type Use	Ground Water	Surface Water	Total
1-6	Municipal and Industrial			
	Cities above 5,000 pop.	124,100	133,700	257,800
	Other Cities	90,100	18,500	108,600
	TOTAL	214,200	152,200	366,400
	Irrigation	4,324,700	219,100	4,543,800
	Mining	52,900		52,900
	TOTAL SUB-AREA 1-6	4,591,800	371,300	4,963,100

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a/ 1964 data used for irrigation
b/ Cities named had populations greater than 5,000 in 1960. All cities with populations below 5,000 were combined.

Source: Texas Water Development Board

2020 Projected Water Demand

Projected water demand for the year 2020 is shown in Table VI-2. The total available fresh groundwater supply was assigned to satisfy as much of the demand as possible. The remaining demand must be satisfied with surface water. Where adequate surface water supplies cannot be developed locally, imports will be required. The Texas Water Plan published in 1968 proposes imports from East Texas and/or the Mississippi River.

Table VI-3 shows projected 2020 municipal and industrial water demands for urban areas that had populations greater than 5,000 in 1960. Demands for all other urban areas are combined.

TABLE VI-2

2020 PROJECTED WATER DEMAND
(Acre-Feet)

Sub-Area	Use	Ground Water	Surface Water		Total
1	Municipal and Industrial	121,400	130,900	a/	252,300
	Irrigation	302,500	4,111,000	b/	4,413,500
	Mining	2,200	-		2,200
	TOTAL SUB-AREA 1	426,100	4,241,900		4,668,000
2	Municipal and Industrial	12,300	123,400	c/	135,700
	Irrigation	14,000	225,200	d/	239,200
	Mining	4,400	-		4,400
	TOTAL SUB-AREA 2	30,700	348,600		379,300
3	Municipal and Industrial	8,000	212,900		220,900
	Irrigation	4,000	25,000		29,000
	Mining	800	-		800
	TOTAL SUB-AREA 3	12,800	237,900		250,700
4	Municipal and Industrial	8,000	75,000		83,000
	Irrigation	3,000	50,000		53,000
	Mining	100	-		100
	TOTAL SUB-AREA 4	11,100	125,000		136,100
5	Municipal and Industrial	43,000	26,200		69,200
	Irrigation	70,100	50,000		120,100
	Mining	-	-		-
	TOTAL SUB-AREA 5	113,100	76,200		189,300
6	Municipal and Industrial	119,900	722,000		841,900
	Irrigation	115,800	429,100		544,900
	Mining	300	-		300
	TOTAL SUB-AREA 6	236,000	1,151,100		1,387,100
1-6	Municipal and Industrial	312,600	1,290,400		1,603,000
	Irrigation	509,400	4,890,300		5,399,700
	Mining	7,800	-		7,800
	TOTAL SUB-AREA 1-6	829,800	6,180,700		7,010,500

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a/ Import of 127,300 acre-feet projected (47,300 from Canadian River)

b/ Import of 4,111,000 acre-feet projected

c/ Import of 40,000 acre-feet projected

d/ Import of 215,600 acre-feet projected

Source: Texas Water Development Board

TABLE VI-3

2020 PROJECTED MUNICIPAL AND INDUSTRIAL WATER DEMAND
(Acre-Feet)

Sub-Area	Urban Area a/	2020 Demand
1	Levelland	8,000
	Littlefield	11,900
	Lubbock	175,900
	Plainview	17,600
	Slaton	4,600
	Other Urban Areas	34,300
	TOTAL SUB-AREA 1	252,300
2	Abilene	75,100
	Breckenridge	3,000
	Stamford	2,500
	Sweetwater	30,300
	Other Urban Areas	24,800
	TOTAL SUB-AREA 2	135,700
3	Bellmead	11,800
	Clebrune	12,800
	Graham	8,500
	Hillsboro	5,300
	Mineral Wells	10,100
	Stephenville	6,800
	Waco	130,600
	Other Urban Areas	35,000
	TOTAL SUB-AREA 3	220,900
4	Belton	5,900
	Cameron	2,200
	Georgetown	5,000
	Killeen	12,300
	Lampasas	3,400
	Taylor	4,400
	Temple	22,400
	Other Urban Areas	27,400
	TOTAL SUB-AREA 4	83,000
5	Brenham	3,600
	Bryan	31,900
	College Station	12,500
	Hearne	3,000
	Marlin	3,500
	Other Urban Areas	14,700
	TOTAL SUB-AREA 5	69,200

TABLE VI-3 (Continued)

2020 PROJECTED MUNICIPAL AND INDUSTRIAL WATER DEMAND
(Acre-Feet)

Sub-Area	Urban Area a/	2020 Demand
6	Alvin	36,100
	Angleton	8,400
	Freeport	288,300
	Galveston	27,400
	Hitchcock	6,400
	Houston (5 percent)	108,400
	Lake Jackson	4,500
	LaMarque	13,500
	Rosenberg	25,000
	Texas City	88,100
	Other Urban Areas	235,800
	TOTAL SUB-AREA 6	841,900
1-6	TOTAL SUB-AREA 1-6	1,603,000

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a/ Urban areas named had populations greater than 5,000 in 1960. All other urban areas were combined.

Source: Texas Water Development Board

VII. SOURCE OF MINERAL POLLUTION

General

Although the area above Possum Kindgom Reservoir contributes an average of only 14 to 18 percent of the runoff from the Brazos River Basin, this area is the source of about 45 to 55 percent of the dissolved-solids, 75 to 85 percent of the chloride, and 65 to 75 percent of the sulfate carried by the Brazos River at Richmond, near the mouth. The percentage varies with the period of record examined. The poor quality of the water in the upper basin is due principally to: 1) natural mineral pollution (inflow of natural sodium chloride brine, particularly in Salt Cronton Creek, a tributary to the Salt Fork; and solution of calcium sulfate from the gypsiferous rocks and soils that are at or near the surface throughout much of the area) and 2) man-made pollution of streams by the disposal of salt water produced with oil. 9/ Table VII-1 shows U. S. Geological Survey estimates of the magnitude of the total mineral pollution load discharged to the Brazos River in the Basin above Possum Kingdom Reservoir for the period 1957-66 water years. Figure III-2 shows the location of streams included in the table. Figure V-3 presents a comparison of U. S. Geological Survey estimates of mineral loads for the WY 1957-66 period with simulated loadings calculated for the period WY 1941-62 using the Basin simulation model.

Natural Mineral Pollution

"The Permian Basin (Figure VII-1) comprises a large area in the southern midcontinent region and includes major portions of Texas, New Mexico, Oklahoma, and Kansas. Within this basin brine springs and seeps discharge more than 20,000 tons per day of sodium chloride." 11/ "In no comparable area of the interior United States are natural sources of salt water so widespread or deleterious to the fresh water supply of so large a segment of the nation's population and industry." 11/

Practically all of the Brazos River Basin above Possum Kingdom Reservoir is within the Permian Basin. Data collected by the U. S. Geological Survey indicate the presence of two distinct bodies of groundwater in this area - shallow fresh water (less than 5,000 mg/l total

TABLE VII-1

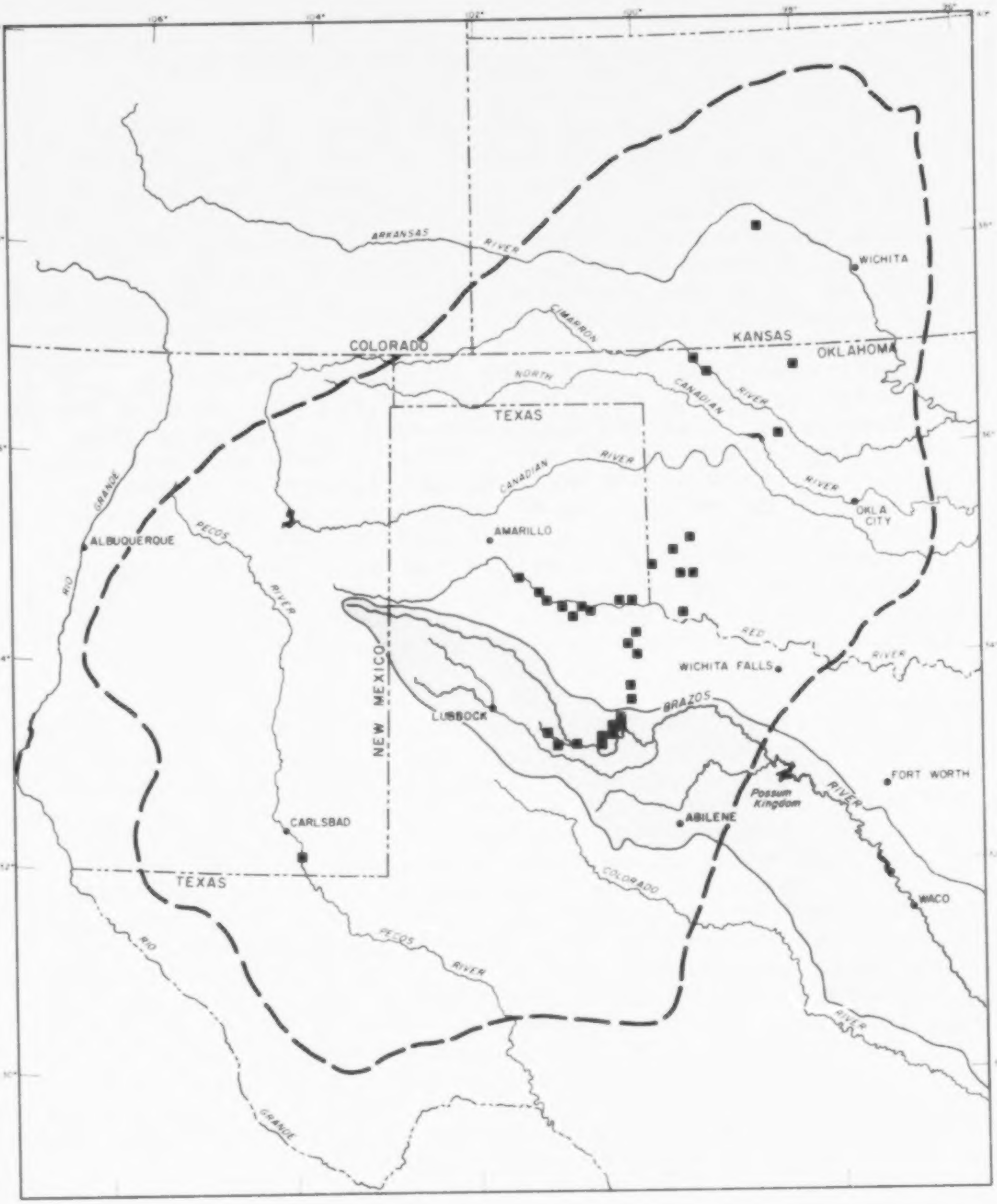
MEAN ANNUAL MINERAL CONTRIBUTION - UPPER BRAZOS RIVER BASIN

1957-66 Water Years

Stream and Location	Drainage Area (square miles) Total	Drainage Area (square miles) Non contrib-uting	Drainage Area (square miles) Contrib-uting	Streamflow Period of Record Years	Streamflow Period of Record Mean Dis-charge (cfs)	Streamflow Mean Dis-charge 1957-66	Flow Weighted Mean Annual Load (tons per day) Dis-Solved Solids	Flow Weighted Mean Annual Load (tons per day) Chloride	Flow Weighted Mean Annual Load (tons per day) Sulfate
Double Mountain Fork Brazos River:									
Red Creek northwest of Rotan	21.2	--	21.2	--	--	3[b]	20	5	8
White Canyon north of Rotan	17.4	--	17.4	--	--	2[b]	16	4	6
Salt Creek southwest of Aspermont	45.4	--	45.4	--	--	6[b]	40	10	15
Double Mountain Fork Brazos River near Aspermont	7980	6470	1510	37	177	189	565	100	235
Salt Fork Brazos River:									
(Above Peacock)									
McDonald Creek near Post	112	--	112	1	1.6	5[b]	40	20	3
Unnamed tributary to Salt Fork - Brazos River near Post	6.3[a]	--	6.3	--	--	0.3[b]	5	2	5
Red Mud Creek near Clairemont	75.8[a]	--	75.8[a]	--	--	4[b]	30	13	5
Salt Creek near Clairemont	36.9[a]	--	36.9[a]	--	--	2[b]	55	30	5
Salt Fork Brazos River near Peacock	4275	2770	1505	4	64.2	78[b]	520	215	85
(Below Peacock)									
Croton Creek near Jayton	310	--	310	7	13.7	16	240	75	80
Salt Croton Creek near Aspermont	64.3	--	64.3	10	7.2	7.2	920	530	35
Salt Fork Brazos River near Aspermont	4830	2770	2060	27	140	119	1760	830	250
Stinking Creek near Aspermont	92.4	--	92.4	1	11.4	5[b]	20	5	6
North Croton Creek near Knox City	251	--	251	1	117	25[b]	190	50	70
Brazos River at Seymour	14490	9240	5250	42	421	379	2520	940	600
Clear Fork Brazos River:									
Hubbard Creek near Breckenridge	1111	--	1111	11	116	125	86	29	5
Clear Fork Brazos River at Eliasville	5721	--	5721	31	399	450[c]	480[c]	165[c]	60[c]
Brazos River at Possum Kingdom Dam near Graford	22550	9240	13260	42	1112	1200	3440	1250	760

[a] Approximate.
[b] Estimated by extension of available records and/or correlation of data from similar areas.
[c] Exclusive of area above Hubbard Creek Reservoir.

Source: U. S. Geological Survey


ARKANSAS RIVER
WICHITA
COLORADO
CIMARRON
KANSAS
OKLAHOMA
NORTH CANADIAN RIVER
TEXAS
CANADIAN RIVER
OKLA CITY
RIO GRANDE
ALBUQUERQUE
PECOS RIVER
AMARILLO
RED RIVER
WICHITA FALLS
NEW MEXICO
LUBBOCK
BRAZOS RIVER
Possum Kingdom
FORT WORTH
ABILENE
CARLSBAD
TEXAS
COLORADO RIVER
WACO
PECOS RIVER
RIO GRANDE

LEGEND:

- PERMIAN BASIN (approximate bound.)
- ■ SITES OF BRINE-DISCHARGE FEATURES

Source: U.S. Geological Survey

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN-TEXAS

PERMIAN BASIN

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE VII-I

dissolved-solids) and a deeper brine. 11/ "Brine movement, though affected locally by the head or thickness of overlying fresh water, has a circulation pattern of its own, independent of local recharge." 11/ The shallow fresh water is predominantly of the calcium sulfate type, presumably owing to solution of gypsum. The brine is predominantly of the sodium-chloride type with a total dissolved-solids concentration averaging about 250,000 mg/l. 11/ "It is . . .reasonable to infer that salt springs and seeps are places where this body of brine crops out, or where it is near the surface and is induced to rise hydraulically and to discharge into valley bottoms where the overlying body of fresh water is very thin or absent. Actual points of discharge seem to be controlled by local geology which determines the distribution of permeability within the locality where the brine is near the surface. The varying salinity of the springs and seeps is explained as due to mixing varying amounts of fresh water with the brine at any one place, although this has not been conclusively demonstrated." 11/

Since 1941, the Geological Survey, in cooperation with the Texas Water Development Board (and its predecessor agencies), the Brazos River Authority, the Corps of Engineers, the U. S. Bureau of Reclamation, and several local agencies, has studied the chemical quality of surface and groundwaters in the Brazos River Basin above Possum Kingdom Reservoir. Since December 1964 the Geological Survey has expanded its data-collection program to provide the Corps of Engineers with data needed to evaluate the benefits of providing remedial measures for reduction of mineral degradation of water resources and to provide data necessary for design of the required control structures. One of the principal objectives of the current program is to locate all significant sources of natural brine or highly saline emissions and to determine the magnitude of their contribution of mineral pollutants.

U. S. Geological Survey studies have shown that the source of sulfate, one of the principal mineral constituents in most of the surface waters, is the solution of calcium sulfate from the surface and near surface rocks and soils by surface runoff. "Calcium sulfate is only slightly soluble in water, and sulfate concentrations rarely exceed 5,000 ppm, and in the concentrated brines sulfate occurs in a ratio of only

1 part to 30 or 40 parts chloride. Thus, the quantity of sulfate contributed by the brine-spring areas is only a fraction of the chloride contribution, and there is no concentrated source of sulfate comparable to the chloride." 9/

"Data from shallow wells driven into the streambed at many sites in the upper Brazos River during the present study appear to confirm that underflow is not a significant source of salt. The streambed deposits appear to be very shallow in many places, especially in tributaries. Many of the streams, which are usually dry at the surface absorb flood waters; but when flood runoff recedes, much of the absorbed water is lost to evaporation and salt accumulates in the streambed and upper layers of sand. Flood flows redissolve the salt deposits and flush them downstream." 9/

There are three principal tributaries above Possum Kingdom Reservoir - Double Mountain Fork, Salt Fork and Clear Fork. Natural mineral pollution in each tributary is discussed below:

Double Mountain Fork

"The principal mineral constituents in runoff from the Double Mountain Fork are calcium and sulfates, although sodium and chloride often predominate in the more concentrated low flows." 9/ Most of the tributaries contribute objectionable quantities of minerals resulting in relatively high concentrations during low flow periods but very saline water (containing 10,000 - 35,000 mg/l dissolved-solids) or brine (containing more than 35,000 mg/l dissolved-solids) has only been observed in Red Creek, White Canyon and Salt Creek (Figure III-3). All of these streams are intermittent; they have no base flow. Apparently salts are deposited within the alluvium and on the surface of the stream channels by evaporation of hidden brine seepage and are later picked up when surface runoff occurs. Although mineral concentrations are very high at times the total load contributed is relatively small (Table VII-1). A large part of the total load is flushed out into the Double Mountain Fork during high flow periods at relatively low concentrations. Yet, there are periods when low flows carry highly mineralized water to the mainstem. Chloride concentrations of low flows from Red

Creek have reached 34,300 mg/l from White Canyon 18,600 mg/l and from Salt Creek 14,800 mg/l.

Salt Fork

"The Salt Fork and most of its tributaries are intermittent throughout much of their drainage. Channels of many of the streams are shallow, braided, and partly choked with sand, silt, and clay. Although most of the streams are dry at the surface, the alluvial fill in the streambed is seldom dry for more than a few feet below the surface." 9/

Only about 26 to 28 percent of the total mineral load contributed by the Salt Fork is collected above Peacock (Figure V-3). Much of this load is collected in small increments from many sources and generally is flushed out into the Salt Fork during high flow periods. Very saline water or sodium chloride brine has only been observed in four streams - an unnamed tributary, McDonald Creek, Red Mud Creek and Salt Creek, northwest of Clairemont. (Figure III-2) Chloride concentrations in the unnamed tributary averages about 28,000 mg/l where there is a base flow of 0.1-0.2 cfs. In McDonald Creek low flows contain as much as 18,800 mg/l chloride. Concentrations of 13,500 mg/l have been measured in Red Mud Creek when flow occurs. Chloride concentrations average 70,000 mg/l at an upstream site on Salt Creek with a 0.1 cfs base flow emerging from a small brine spring. Farther downstream the Creek is intermittent and much of the flow is absorbed in the alluvium. None of these tributaries discussed contribute major quantities of minerals (Table VII-1).

Below Peacock high mineral concentrations, predominantly sodium chloride have been observed in Croton Creek, Short Croton Creek, Hot Springs Canyon, Salt Croton Creek, Haystack Creek, Dove Creek, Stinking Creek, and North Croton Creek (Figure III-2).

Seeps and springs at the salt flats on Hot Springs Canyon, Short Croton, Dove, and Haystack Creeks discharge brine to the stream channels. "Discharge at the salt flats on Hot Springs and Short Croton Creek is facilitated by fractures and solution openings in a bed of gypsum that crops out at the margins of these salt flats. Analysis of water from springs issuing from this gypsum indicate that the water is probably a mixture of about two parts fresh water and one part brine." 11/ Similar conditions exist in the vicinity of the Dove Creek salt falt. 11/

In Croton Creek below the salt flats brine seepage to the alluvium appears to be contributed in small increments throughout most of the reach. Croton Creek and its tributaries are dry much of the time. Low flows from the upper basin are often absorbed further downstream by the unsaturated alluvium, yet the quantity of water that moves downstream as underflow is probably insignificant. 9/ Water in the alluvium appears to be stagnent. 9/ Salt loads are flushed out into the Salt Fork when runoff occurs. Chloride concentrations generally exceed 10,000 mg/1 when the stream is flowing while low flows through the salt flats often exceed 20,000 mg/1. Croton Creek contributes almost 15 percent of the total mineral load collected by the Salt Fork of the Brazos River (Table VII-1).

The largest portion of the salt load of the Brazos River originates from seeps and springs in the Salt Croton Creek drainage area, primarily from the Dove and Haystack Creek salt flats. (Figure III-2) The base flow for water years 1957-66, measured 0.1 mile below Haystack Creek averaged about 1 cfs of concentrated brine frequently exceeding 100,000 mg/1 chloride. Salt Croton Creek contributes about 45 to 55 percent of the total mineral load collected by the Salt Fork of the Brazos River (Table VII-1 and Figure V-3).

Small but significant quantities of mineral pollutants are collected in Stinking Creek. Specific sources have not been located.

North Croton Creek contributes about 9 to 10 percent of the total mineral load collected by the Salt Fork of the Brazos River. Part of this load originates from seeps and springs in the drainage area of a small tributary - Salt Creek where chloride concentrations often approach 90,000 mg/1.

Clear Fork

"Chemical-quality records for the Clear Fork and tributaries indicate that surface water of the Clear Fork ususally is fresh, except in areas where pollution by oil-field brine is occurring." 9/ Natural brine seepage has not been detected.

Man-Made Mineral Pollution

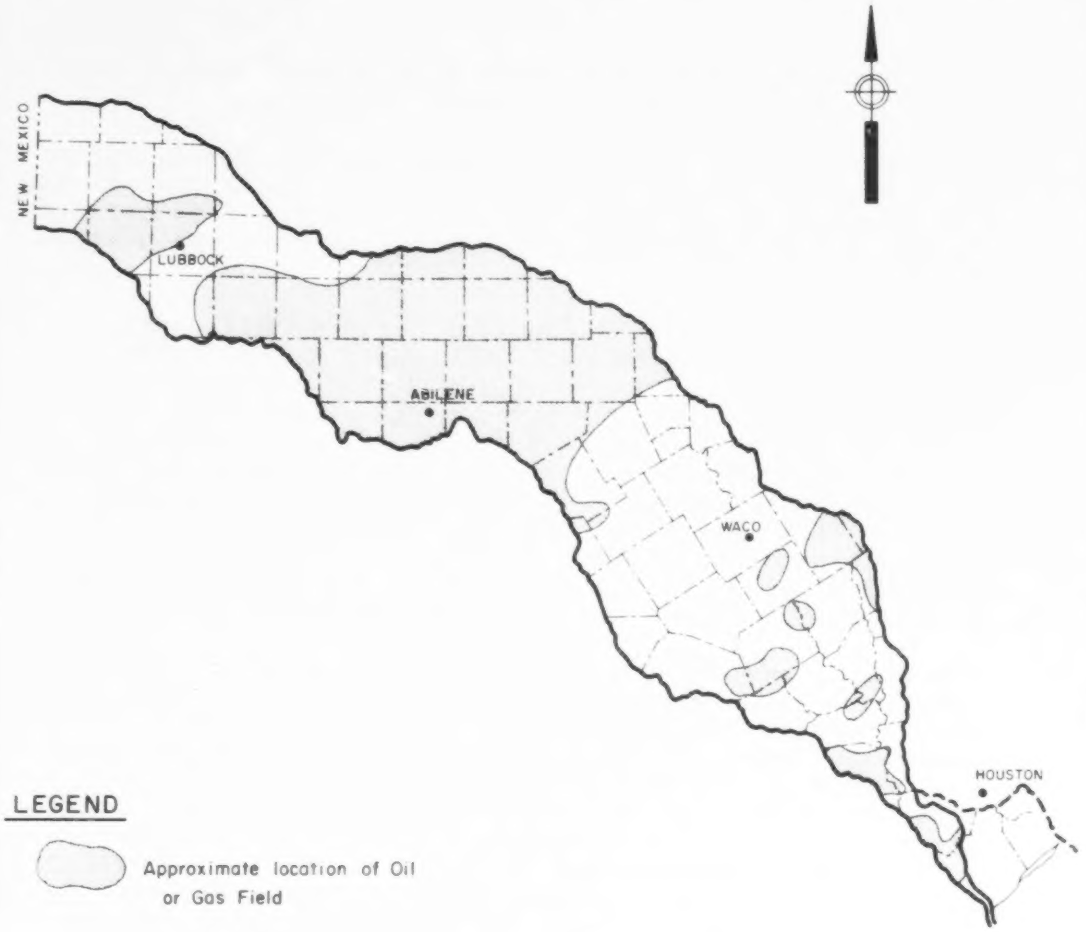
Oil Field Pollution

Oil fields are widely distributed in the Brazos River Basin (Figure VII-2) and salt water (brine) is pumped to the surface with the oil in nearly every field. The amount of brine produced in proportion to the oil produced generally increases as the fields become older.

"If improperly handled, the salt eventually reaches surface streams. According to an inventory by the Texas Railroad Commission in 1961, more than 93 percent of the salt water produced in oil fields of the Brazos River Basin was injected underground to prevent and abate pollution or to increase oil production. 12/ The remainder of the salt water was disposed of in open surface pits, most of which were unlined. From these so-called evaporation pits, much of the brine has percolated into the ground and has seeped, or eventually will seep, into the streams of the basin. Since the beginning of salt water production, some of the brine has always been washed by surface runoff directly into streams when the pits were breached or overflowed, when pipelines leaked, or when the brine was deliberately dumped. In addition, brine from abandoned wells and unplugged or improperly plugged test holes may find its way into streams. Also, injected brine may move upward in old wells or test holes, or along fault zones, and again reach the surface.

Effect of oil field brines on water quality in the upper Brazos River Basin is most evident in the Clear Fork Brazos River and its tributaries and in the lower Brazos River Basin is most evident in the Navasota River.

Hembree and Blakey (1964) 13/ have shown that the surface waters of the Hubbard Creek watershed were by nature originally low in chloride content but had shown a progressive increase in chloride since about


NEW MEXICO
LUBBOCK
ABILENE
WACO
HOUSTON
LEGEND
Approximate location of Oil or Gas Field

SOURCE:
TEXAS WATER DEVELOPMENT BOARD
REPORT 55

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

MAJOR OIL PRODUCTION

ENVIRONMENTAL PROTECTION AGENCY

REGION VI
DALLAS, TEXAS

FIGURE VII-2

1955--this increase coinciding with an increase in water flood projects in the oil fields.

Shamburger (1958) 14/, after investigating the salinity of California Creek, concluded that oil field operations had resulted in artesian flow of salt water from springs in the bed of California Creek and from open exploration holes.

On the basis of 1949-53 chemical quality data on the Clear Fork and 1955-59 data on Hubbard Creek, Baker, Hughes, and Yost (1964, p. CC49-50) 15/ calculated the average daily load contributed by the Clear Fork Brazos River at 320 tons dissolved-solids, 75 tons chloride and 50 tons sulfate . . .Subsequent data show that this load has increased markedly, and for the base period . . . ., 1957-66, was about 480 tons dissolved-solids, 165 tons chloride and 60 tons sulfate . . . This increase in load could only be the result of oil field activities, as has been documented in the Hubbard Creek watershed.

The use of surface pits for the disposal of oil field brine has been decreasing steadily . . ., and perhaps the effect of oil field pollution on streams will gradually decrease. But the salt that has seeped into the ground as the result of past activities will continue to affect the quality of ground and surface water for many years. The accepted disposal method-injection of salt water underground for disposal or for water flooding oil fields has many potential hazards, and unless the disposal projects are properly engineered and operated, injected brine will continue to be a source of salt pollution in the upper Brazos River Basin. Programs for plugging abandoned wells, such as are being conducted in the Hubbard Creek area, may be required in other areas for the control of oil field pollution." 9/

Pollution as Result of Water Use

Only a portion of the water drawn from groundwater aquifers or surface sources is depleted by mans use in irrigation, industrial processes and for municipal water supplies. More than half of the water developed finds its way back to the stream system as waste water. This waste carries a significant mineral load to the basin streams. One cycle of use in a municipal system may raise the total dissolved-solids concentration more than 200 mg/l and the source concentration of the irrigation and many industrial supplies may be doubled by a single cycle of use. As water demands increase, return flows increase, resulting in a gradual climb to higher mineral concentrations in the stream system.

VIII. WATER SUPPLY AND WATER QUALITY CONTROL

General

Severe restrictions of use are imposed on water resources in the Brazos River Basin by quality degradation. Quality improvement will be required to effectively develop the available water resources for supplying projected water needs through the year 2020.

Water Supply

The dominant water supply objective of this study was to fully utilize the water resources of the Study Area to satisfy water needs within that same area while limiting imports to minimum quantities.

Plans prepared by the State of Texas for meeting water demands of the state through the year 2020 apportion Texas resources throughout the state. Even with maximum utilization of groundwater resources and re-use of waste water return flows, Texas resources are not expected to fully meet projected 2020 demands without imports. Importation to Texas from other states has met some resistance. It seems likely that imports will not be authorized until the State of Texas can demonstrate that all resources within the boundary of Texas are fully utilized.

Effective use of the Brazos River Basin water resources is essential not only to the Basin area but to the entire State of Texas. If use of in-basin resources is restricted or prevented by poor quality, then a portion of the available good quality resources from other areas must be shared with the Brazos Basin. No doubt other areas of the state will object to sharing of their limited supplies unless they can be assured that every possible effort has been made to meet the Brazos Basin demands with its own resource.

The projected water demand for the year 2020 (Table VI-2) cannot be fully satisfied with study area resources. Imports will be required to prevent or reduce deflation of potential developmental pressures in sub-areas 1 and 2 (Figure III-1) of the study area. Water demands in sub-areas 3 through 6 can be satisfied with study area resources. A brief discussion of demands and supplies is presented below. Table VI-2 shows the proportion of demand to be supplied with groundwater, surface water and imports. A detailed distribution of supplies is presented in Appendix B for use in the basin mathematical model. This distribution does not include sub-area 1 or imports for sub-area 2.

Sub-Area 1

This sub-area is supplied primarily by groundwater with very limited in-basin surface water supplies and imports from the Canadian River Basin. It will be necessary to greatly reduce groundwater withdrawal in this sub-area prior to the year 2020. If some means of importing water from other basins cannot be found, the irrigated agricultural industry will be severly damaged. Municipal and industrial water demands of the deflated economy could be satisfied with resources available in the sub-area. To maintain a viable economy, imports of 47,300 acre-feet per year from the Canadian River Basin and 4,191,000 acre-feet per year from some other source will be needed by the year 2020. These water imports would supply 4,111,000 acre-feet per year for irrigation and 127,300 acre-feet per year for municipal and industrial use.

Sub-Area 2

Groundwater resources are limited in quantity and are very poor in quality yet they are used rather extensively in some areas for irrigation and are essential for small urban, farm and ranch supplies. If surface water could be imported, dependance on groundwater for irrigation most likely would diminish. Although local supplies could meet the demands if the quality was improved; if import water was available, it would possibly be desirable to import some water (40,000 acre-feet per year) from other basins for meeting municipal and industrial demands to assure higher quality supplies. Degradation of surface water resources by oil field operations and natural brine emissions must be greatly reduced to allow unrestricted use of the sub-area 2 resources.

Sub-Area 3

Groundwater resources are limited both in quantity and quality. Surface water resources from the main stem of the Brazos River would be sufficient to supply the total demands of the sub-area, however, use of tributary supplies has been necessary due to the poor quality of the main stem and continued use of existing supply systems will be necessary. Therefore, a portion of the demand will be supplied from the main stem but much of the main stem resource will continue to be allowed to flow through sub-area 3 for use further downstream. Main stem supplies will not be planned until quality improvements can be assured. A portion of the surface water resources of sub-area 4 will be used in sub-area 3.

Sub-Area 4

Groundwater resources are limited both in quantity and quality. However, their use is essential for small urban, farm, and ranch supplies. Surface water resources are more than adequate in quantity and quality but are not evenly distributed. A large portion of the sub-area cannot be economically supplied with surface water and must continue to use poorer quality groundwater supplies while the surface water resources are utilized in the sub-area 3, Waco urban complex, and in sub-area 6 service areas.

Sub-Area 5

Groundwater resources are generally good both in quantity and quality and are used almost exclusively for present supplies. Much of the surface water resource is not needed locally and can be utilized in sub-area 6.

Sub-Area 6

Groundwater resources are extensive and are generally good in quality. They are not extensive enough, however, to meet the water demands. Heavy withdrawal in some areas has produced land subsistence and possibly will have to be reduced. Surface water runoff is heavy but reservoir sites are very limited. Surface water supplies must be developed in other parts of the basin for supplying large sub-area 6 demands.
Surface water resources surplus to other sub-areas in the Brazos Basin will be sufficient in quantity to supply the surface water demands of sub-area 6. It will be necessary, however, to use the main stem of the

Brazos River for transporting the supplies to sub-area 6. Good quality supplies can not be provided in this manner until salinity control programs are instituted.

Water Quality Control

This study of the Brazos River Basin has been specifically directed toward an analysis of the occurrence and control of dissolved mineral constituents in surface waters and is further limited to a detailed analysis of chloride, sulfate and total dissolved-solids since these constituents are believed to be most critical.

There are, of course, many diverse needs for water. Some uses are sensitive to mineral constituents and require rigid control of their concentration while other uses are less sensitive and a broad range of concentrations can be tolerated. As a general rule, however, public systems are developed to provide water acceptable for potable supplies. This approach generally accommodates the majority of the water users and has been used to establish the goals for quality control in the Brazos River Basin.

The dominant water quality objective was to devise methods for adjusting the quality of study area water resources to obtain supplies that would meet the Public Health Service Drinking Water Standards - 1962. 6/ However, this objective could not be met in all cases and it became necessary to define the utility of supplies with mineral concentrations that exceed the recommended limits. A secondary objective then became to plan supplies with qualities that would be similar to the quality of supplies already developed in other areas in Texas that were acceptable to the people living in those area.

Established Water Quality Standards

Public Health Service Drinking Water Standards - 1962 6/ state, "The importance of chloride, sulfate, and dissolved-solids as they affect water quality hinges upon their taste and laxative properties. There is evidence that excessive amounts of these constituents cause consumer reaction which may result in individual treatment or rejection of the supply. Therefore, limiting amounts for these chemical constituents have been included in the standards." These standards recommend that chloride should not exceed 250 mg/l, sulfates 250 mg/l, and dissolved-solids 500 mg/l where other suitable supplies are, or can be made available. Of course, the total dissolved-solid concentration would exceed 500 mg/l if both chlorides and sulfates reached 250 mg/l, therefore, the standards are much more restrictive then they first appear. Actually, water with a sulfate concentration of 250 mg/l and a chloride concentration of 100 mg/l would contain approximately 500 mg/l of dissolved-solids.

The World Health Organization Internationaal Standards 16/ set chloride, sulfate and total dissolved-solids concentration highest desirable limits of 200,200 and 500 mg/l respectively with maximum permissable limits of 600,400 and 1500 mg/l. The World Health Organization European Drinking Water Standards 17/ recommended a limit of 200 mg/l for chloride with a maximum limit of 600 mg/l. The recommended sulfate limit is 250 mg/l. These standards do not include limits for total dissolved-solids.

Taste

"Because of absence of significant physiological affects, the controlling factor limiting total mineral content in domestic water will very likely be its general taste quality." 18/

"The taste of water is affected by the common dissolved minerals: calcium, magnesium, potassium, sodium, bicarbonate, carbonate, nitrate, chloride and sulfate. Collectively these constituents make up most of the dissolved-solids in water. 18/

Public Health Service Drinking Water Standards 6/ for chlorides, sulfates, and total dissolved-solids are primarily based on threshold taste tests. A threshold is the amount of dissolved material per unit volume of solvent that is just barely, but reliably, detectable by each member of a sensory panel. Standards have been conservatively set because detection thresholds for an extremely large number of consumers were estimated by only a small panel. The adoption of threshold concentrations as standard assumes that any detectable mineral taste in water is unacceptable. The Public

Health Service recognized that this assumption is not totally valid; they state "It should be emphasized that there may be a great difference between a detectable concentration and an objectionable concentration of the neutral salts." 6/ and "Relatively little information is available on consumer attitudes toward mineralized water." 6/ Since 1962 when the Public Health Service Drinking Water Standards were last revised, additional research has been conducted to develop a procedure to establish a functional relation between mineral content in water and consumer attitude toward taste. The procedure used was similar to that used by the food industry to determine consumer evaluation of various products and beverages. In a test of the procedure in California, both consumer and taste panel evaluations were obtained by the research to fully describe the general taste quality of the waters studied. "The major finding of the consumer survey research indicated an inverse linear relationship between general taste quality and total mineral content." 18/ It was recognized that individual mineral anions may have widely differing effects upon taste quality, however, analysis of data collected in the California survey indicated that the consumer attitude prediction using total dissolved-solids content was not significantly different from predictions that accounted for individual anion content. Additional " . . .work might yield a multivariate function relating major ionic concentrations to taste evaluation. Unfortunately, the present data give no clear indication what such a function might be since, for the waters here studies, all major ionic constituents correlated highly with total dissolved-solids." 18/ In his April 13, 1971, letter discussing his survey, 18/ Dr. William H. Bruvold did say "As far as taste is concerned, chloride measured in mg/1, has a more pronounced effect than sulfate. The latter seems to yield a flat chalky taste, while, surprisingly, chloride seems to give water a bad or unpalatable taste. A 1000 mg/1 total dissolved-solid water consisting mainly of chlorides would likely be judged unacceptable for daily drinking, while the same concentration of dissolved sulfates might be judged acceptable."

Attitude test results were used to develop scales for predicting potability of water supplies in California. A score of 6.0 on attitude tests used in the consumer survey 18/ represents a neutral attitude. Higher scores represent favorable attitudes, and scores lower represent unfavorable attitudes. Following in Table VIII-1 is a grading scale based upon the percent of individual scores above or below 6.0, the neutral point.

Laxative Effects

Both sodium sulfate and magnesium sulfate are well known laxatives. Laxative effect is commonly noted by newcomers and casual users of waters high in sulfates. However, one evidently becomes acclimated to use of these waters in a relatively short time. "The North Dakota State Department of Health has collected information on the laxative effects of water as related to mineral quality. This has been obtained by having individuals submitting water samples for mineral analysis complete a questionnaire which asks about the taste and odor of the water, its laxative effect (particularly on those not accustomed to using it), its effect on coffee, and its effect on potatoes cooked in it."

Peterson . . . and Moore . . . have analyzed part of the data collected, particularly with regard to the laxative effect of the water.

"Peterson found that, in general, the waters containing more than 750 mg/1 of sulfate showed a laxative effect and those with less than 600 mg/1 generally did not. If the water was high in magnesium, the effect was shown at lower sulfate concentrations than if other cations were dominant. Moore showed that laxative effects were experienced by the most sensitive persons, not accustomed to the water, when magnesium was about 200 mg/1 and by the average person when magnesium was 500-1,000 mg/1." 6/

The Public Health Service concluded that "Cathartic effects are commonly experienced with water having sulfate concentrations 600 to 1,000 mg/1, particularly if much magnesium or sodium is present. 6/

Potability Scale for the Brazos River Basin

The Public Health Service states "Although waters of such quality are not generally desirable, it is recognized that a considerable number of supplies with dissolved-solids in excess of the recommended limits are used without any obvious ill effects." 6/ A report 19/ prepared by the Southwest Research Institute

TABLE VIII-1

CALIFORNIA POTABILITY SCALE 18/

Grades by Total Dissolved-Solids (TDS)(mg/l) as defined by the percent scoring above the neutral point on five tests of general taste.

	Quality				
Potability Grade	Excellent A	Good B	Fair C	Poor D	Unacceptable F
% >Neutral	100-85	84- 75	74- 65	64- 55	54-0
TDS for TEST 1	≤67	68-384	385- 702	703-1010	≤1020
TDS for TEST 2	≤287	288-630	631- 972	973-1315	≤1316
TDS for TEST 3	≤444	445-768	769-1093	1094-1418	≤1419
TDS for TEST 4	≤521	522-874	875-1226	1227-1578	≤1579
TDS for TEST 5	≤276	277-632	633- 988	989-1329	≤1330
Mean TDS	≤319	320-658	659- 996	997-1332	≤1333

Note:
This scale, of course, was developed for the State of California and may not be universally applicable. Many mineral analyses of test cities do, however, appear very similar to waters of the Brazos Basin, therefore, a modified form of the scale was utilized to estimate the potability of future study area supplies. A potability scale for the Brazos River Basin is presented later in this Chapter.

and the Texas Water Development Board for the Office of Saline Water shows an evaluation of all communities in Texas with one thousand or more population in the 1960 U. S. Census. This evaluation shows that 50.3 percent of the 586 communities use water supplies with total dissolved-solids concentrations exceeding 500 mg/1; 6.4 percent have sulfates exceeding 250 mg/1 and 9.7 percent have chlorides exceeding 250 mg/1. A report 20/ prepared by Black and Veatch list data on 1870 communities in the United States with populations exceeding 1,000. Of the 742 communities reporting mean total dissolved-solids concentrations, 32.3 percent were equal to or greater than 500 mg/1.

Table VIII-2 lists some communities greater than 10,000 population in 1960 that use supplies with total dissolved-solids exceeding 500 mg/1. It is interesting to note that one of the largest municipal supplies in the United States, in the Southern California area supplied by the Colorado River, does not conform to Public Health Service standards for mineral content. Water appropriated from the Colorado River averages approximately 285 mg/1 SO_4, 90 mg/1 Cl, and 760 mg/1 TDS.

The mineral content of water presently used for supplies within the study area in many cases exceeds U. S. Public Health Service Drinking Water Standards - 1962 recommended limits. Table VIII-3 is a list of cities that had populations greater than 1,000 in 1960 showing representative mineral quality of their potable water supplies.

It should be apparent from the discussion above that potable water supplies, although not as desirable, can be successfully developed where total dissolved-solids and/or individual anions exceed the Public Health Service recommended limits. 6/ Most of the resources available in the Brazos now and in future years, even with salinity control, will exceed one or more of these limits but the resources must be developed to meet in-basin demands.

The scale in Table VIII-4 has been adopted to evaluate the success of salt control plans for development of potable water resources within the study area. Of course, the ideal objective is to produce "Excellent" quality supplies, where possible, that have mineral concentrations well below the Public Health Service

TABLE VIII-2

COMMUNITIES WITH POPULATIONS OF 10,000 OR GREATER THAT HAVE TDS CONCENTRATIONS EXCEEDING 500 mg/l IN THEIR POTABLE WATER SUPPLY

Community	Population	TDS (mg/l)	
		Avg.	Max.
Chandler, Arizona	10,000	875	
Mesa, Arizona	50,000	712	
Phoenix, Arizona	550,000	638	2000
Tempe, Arizona	40,000	1000	1442
Tucson, Arizona	253,760	600	645
Metro. Water Dist. - Los Angeles, California	9,000,000	681	710
Compton, California	55,500	508	
Conservative Water Co. - Los Angeles, California	60,000	777	1110
Eastern Mun. Water Dist. - Hemet, California	42,500	681	703
El Centro, California	20,000	800	860
Fallbrook Public Util. Dist. - Fallbrook, California	10,300	850	700
Garden Grove, California	103,000	600	700
Los Angeles Co. WWD #13 - Lomita, California	16,500	650	680
Newport Beach, California	32,468	678	
Oceanside, California	31,000	660	660
Oxnard, California	50,000	1150	1450
Pasadena, California	139,000	520	770
Pamona Valley MWD - Pamona, California	180,000	681	
Port Hueneme, California	11,500	950	1350
San Diego, California	620,000	750	775
San Diego Water Authority - San Diego, California	1,100,000	683	704
San Gabriel Valley Water Co. - El Monte, California	46,644	560	635
Santa Ana, California	108,000	513	763
Santa Barbara, California	60,000	550	550
Santa Marie, California	32,000	672	1242
Santa Paula Water Works, Ltd. - Santa Paula, California	15,000	800	975
Ventura, California	50,000	1100	1500
Ventura River MWD - Oakview, California	45,000	717	908
Sarasota, Florida	38,000	1400	1600
Vero Beach, Florida	12,000	630	
Ames, Iowa	24,000	510	
Arkansas City, Kansas	14,698	773	
Hutchinson, Kansas	38,000	995	1410
Salina, Kansas	45,000	600	1200
Lead Belt Water Co. - Flat River, Missouri	10,000	600	688
Las Vegas Valley Water Dist. - Las Vegas, Colorado	80,000	570	1006
Artesia, New Mexico	12,000	750	
Gallup, New Mexico	16,000	600	894
Las Cruces, New Mexico	29,000	862	862
Roswell, New Mexico	50,000	1100	1400

TABLE VIII-2 (Continued)

Community	Population	TDS (mg/l)	
		Avg.	Max.
Jamestown, North Dakota	15,000	894	1113
Minot, North Dakota	33,477	759	915
Reynoldsburg, Ohio	10,500	648	670
Zanesville, Ohio	38,000	700	
Oklahoma City, Oklahoma	350,000	535	575
Conway, South Carolina	10,000	650	
Georgetown, South Carolina	14,000	539	599
Brookings, South Carolina	11,500	700	1000
Huron, South Carolina	15,000	1100	1600
Sioux Falls, South Carolina	70,000	610	1140
Andrews, Texas	12,000	1000	
Baytown, Texas	36,000	764	1154
Beeville, Texas	15,000	1120	1120
Bryan, Texas	32,000	600	1000
Eagle Pass, Texas	12,500	570	882
El Paso, Texas	300,000	800	1290
Ennis, Texas	10,200	2141	2141
Harlingen, Texas	38,000	900	1300
Hurst, Texas	15,200	960	
Kingsville, Texas	25,297	800	
Lake Jackson, Texas	11,500	1000	1110
Lamesa, Texas	13,000	900	900
Laredo, Texas	65,000	770	900
Lubbock, Texas	142,000	600	1000
Mercedes, Texas	12,000	1605	1605
Midland, Texas	65,000	1157	
Odessa, Texas	85,000	600	700
Palestine, Texas	15,000	600	820
Pecos, Texas	13,250	1500	
Sherman, Texas	24,988	767	1286
Texas City, Texas	33,000	1070	1200

Source: Office of Saline Water
Research and Development Progress Report No. 162

TABLE VIII-3

MUNICIPAL SUPPLY WATER QUALITY

Sub-Area 1

City	County	1960 Pop.	Representative Mineral Concentrations (mg/1) Total Solids	Sulfate	Chloride	Water Use Annual Million Gallons	Gallons Per Capita
			SURFACE SUPPLY				
Ralls	Crosby	2,229	520	56	102	77	94
Spur	Dickens	2,170	710	93	76	131	165
Post	Garza	4,663	710	93	76	248	145
			GROUNDWATER SUPPLY				
Muleshoe	Bailey	3,871	660	121	91	195	138
Lorenzo	Crosby	1,188	500	33	19	23	54
Rotan	Fisher	2,788	386	70	31	82	80
Floydada	Floyd	3,769	520	32	18	171	124
Lockney	Floyd	2,141	580	30	38	97	124
Abernathy	Hale	2,451	500	38	33	158	173
Hale Center	Hale	2,196	475	24	21	127	159
Petersburg	Hale	1,400	397	32	16	41	161
Plainview	Hale	18,735	499	24	20	1252	183
Seth Ward	Hale	1,328	499	24	20	-	-
Anton	Hockley	1,068	1590	590	271	51	129
Levelland	Hockley	10,153	770	201	72	600	161
Earth	Lamb	1,104	461	33	28	52	130
Littlefield	Lamb	7,236	451	30	17	466	176
Olton	Lamb	1,917	445	22	23	191	273
Sudan	Lamb	1,235	833	227	90	108	240
Idalou	Lubbock	1,274	510	35	27	50	108
Lubbock	Lubbock	128,691	660	120	52	6675	141
Reese Village	Lubbock	1,800	-	-	-	-	-
Shallowater	Lubbock	1,001	1000	227	132	20	55
Slaton	Lubbock	6,568	770	118	69	261	109
O'Donnel	Lynn	1,356	2000	460	410	29	58
Tahoka	Lynn	3,012	870	195	175	142	129
Bovina	Parmer	1,029	342	27	13	36	96
Farwell	Parmer	1,009	365	25	15	46	125
Aspermont	Stonewall	1,286	720	57	56	61	130

Source: Office of Saline Water "Research and Development Progress Report No. 250."

TABLE VIII-3

MUNICIPAL SUPPLY WATER QUALITY

Sub-Area 2

City	County	1960 Pop.	Representative Mineral Concentrations (mg/1) Total Solids	Sulfate	Chloride	Water Use Annual Million Gallons	Gallons Per Capita
			SURFACE SUPPLY				
Baird	Callahan	1,633	185	15	10	79	131
Anson	Jones	2,890	1100	247	170	125	118
Hamlin	Jones	3,791	351	46	34	179	123
Stamford	Jones	5,259	439	47	49	497	168
Sweetwater	Nolan	13,914	321	50	34	118	270
Albany	Shackelford	2,174	489	49	151	182	228
Breckenridge	Stephens	6,273	292	22	58	314	137
Abilene	Taylor	90,368	399	43	71	5492	166
Merkel	Taylor	2,312	357	34	55	-	-
			GROUNDWATER SUPPLY				
Seymour	Baylor	3,789	760	69	83	220	158
Clyde	Callahan	1,116	690	120	188	32	79
Haskell	Hasekll	4,016	1160	139	243	180	123
Rule	Haskell	1,347	900	83	107	89	180
Knox City	Knox	1,805	1130	223	149	65	98
Munday	Knox	1,978	1730	401	331	58	80
Roscoe	Nolan	1,490	640	108	88	44	81

Source: Office of Saline Water "Research and Development Progress Report No. 250."

TABLE VIII-3

MUNICIPAL SUPPLY WATER QUALITY

Sub-Area 3

City	County	1960 Pop.	Representative Mineral Concentrations (mg/l)			Water Use	
			Total Solids	Sulfate	Chloride	Annual Million Gallons	Gallons Per Capita
			SURFACE SUPPLY				
Cleburne a/	Johnson	15,381	95	18	13	603	132
Beverly Hills	McLennan	1,728	240	33	37	-	-
Mart a/	McLennan	2,197	960	123	47	148	185
Waco a/	McLennan	97,808	240	33	21	5447	152
Mineral Wells	Palo Pinto	11,053	201	43	11	822	203
Graham	Young	8,505	269	12	111	471	151
Olney	Young	3,872	445	16	189	209	147
			GROUNDWATER SUPPLY				
Clifton	Bosque	2,335	695	52	17	86	103
Valley Mills	Bosque	1,061	740	79	16	23	60
Stephenville	Erath	7,359	530	23	27	360	134
Hillsboro	Hill	7,402	1361	409	55	243	90
Itaska	Hill	1,383	2440	1360	38	33	65
Whitney	Hill	1,050	990	237	43	31	80
Grandbury	Hood	2,227	710	72	34	117	143
Bellmead	McLennan	5,127	600	89	44	130	69
Lacy Lake View	McLennan	2,272	860	130	43	75	91
McGregor	McLennan	4,642	990	180	59	101	59
Moody	McLennan	1,074	936	93	171	37	93
Robinson	McLennan	2,111	900	147	48	45	-
West	McLennan	2,352	790	80	49	92	107
Woodway	McLennan	1,244	-	-	-	17	37

a/ Mixed ground and surface supply

Source: Office of Saline Water "Research and Development Progress Report No. 250."

TABLE VIII-3

MUNICIPAL SUPPLY WATER QUALITY

Sub-Area 4

City	County	1960 Pop.	Representative Mineral Concentrations (mg/1) Total Solids	Sulfate	Chloride	Water Use Annual Million Gallons	Gallons Per Capita
			SURFACE SUPPLY				
Kileen	Bell	23,377	145	25	30	632	74
Temple a/	Bell	30,419	174	22	32	1335	120
Comanche	Comanche	3,415	222	15	14	114	91
Copperas Cove	Coryell	4,567	200	36	54	106	63
Cisco	Eastland	4,499	211	16	15	307	186
Eastland	Eastland	3,292	253	27	48	176	146
Ranger	Eastland	3,313	253	27	48	-	-
Hamilton a/	Hamilton	3,106	399	51	94	128	112
Lampasas	Lampasas	9,061	770	117	96	256	138
Cameron	Milam	5,640	312	28	34	236	114
			GROUNDWATER SUPPLY				
Belton	Bell	8,163	1600	330	289	312	105
DeLeon	Comanche	2,022	730	51	138	48	65
Gatesville	Coryell	4,626	1452	285	258	202	119
Gorman	Eastland	1,142	346	14	41	63	151
Hico	Hamilton	1,020	550	50	28	46	125
Rockdale	Milam	4,481	217	33	63	183	111
Bartlett	Williamson	1,540	1440	305	266	43	76
Georgetown	Williamson	5,218	434	23	22	292	153
Granger	Williamson	1,339	1440	264	301	56	114
Round Rock	Williamson	1,878	580	27	18	36	53
Taylor	Williamson	9,434	1261	280	188	343	99

a/ Mixed ground and surface supply

Source: Office of Saline Water "Research and Development Progress Report No. 250."

TABLE VIII-3

MUNICIPAL SUPPLY WATER QUALITY

Sub-Area 5

City	County	1960 Pop.	Representative Mineral Concentrations (mg/1)			Water Use	
			Total Solids	Sulfate	Chloride	Annual Million Gallons	Gallons Per Capita
			SURFACE SUPPLY				
Throckmorton	Brazos	1,299	520	24	204	65	136
Crosbyton	Crosby	2,088	418	42	25	94	122
Marlin	Falls	6,918	213	27	17	350	138
Rosebud	Falls	1,644	230	108	10	43	72
Grosebeck	Limestone	2,498	580	23	242	89	98
Mexia	Limestone	6,121	173	36	34	195	87
			GROUNDWATER SUPPLY				
Bryan	Brazos	27,542	820	4	53	1340	133
College Station	Brazos	11,396	640	15	51	209	50
Caldwell	Burleson	2,204	499	55	20	76	94
Somerville	Burleson	1,177	1520	391	176	43	100
Sunrise	Falls	1,708	710	149	220	-	-
Navasota	Grimes	4,937	965	22	216	152	84
Calvert	Robertson	1,950	1107	3	106	51	67
Franklin	Robertson	1,065	286	10	15	28	73
Hearne	Robertson	5,072	640	5	41	265	143
Brenham	Washington	7,740	560	3	46	256	90

Source: Office of Saline Water "Research and Development Progress Report No. 250."

TABLE VIII-3

MUNICIPAL SUPPLY WATER QUALITY

Sub-Area 6

City	County	1960 Pop.	Representative Mineral Concentrations (mg/l) Total Solids	Sulfate	Chloride	Water Use Annual Million Gallons	Gallons Per Capita
			GROUNDWATER SUPPLY				
Bellville	Austin	2,218	650	49	61	94	116
Sealy	Austin	2,328	233	5	57	66	78
Alvin	Brazoria	5,643	852	10	222	261	126
Angleton	Brazoria	7,312	837	11	128	207	77
Brazoria	Brazoria	1,291	2205	3	424	33	69
Clute	Brazoria	4,501	910	12	135	125	76
Freeport a/	Brazoria	11,619	595	1	123	539	127
Lake Jackson	Brazoria	9,651	850	37	197	215	61
Pearland	Brazoria	1,497	500	5	53	36	66
Sweeny	Brazoria	3,087	820	23	129	65	58
West Columbia	Brazoria	2,947	920	5	320	88	82
Richmond	Fort Bend	3,668	385	17	46	146	109
Rosenberg	Fort Bend	9,698	430	11	54	278	70
Sugarland	Fort Bend	2,802	460	16	57	254	248
Alta Loma	Galveston	1,020	923	0	165	15	39
Bacliff	Galveston	1,707	660	4	164	-	-
Dickinson	Galveston	4,715	630	3	84	146	85
Galveston	Galveston	67,175	1100	3	389	4345	177
Hitchcock	Galveston	5,216	650	5	105	144	75
LaMarqe	Galveston	13,969	1057	0	324	416	82
League City	Galveston	2,622	617	0	95	71	74
Texas City	Galveston	32,065	920	5	167	926	79
Brookshire	Waller	1,339	398	11	65	36	74
Hempstead	Waller	1,505	570	6	45	77	140

a/ Mixed ground and surface supply

Source: Office of Saline Water "Research and Development Progress Report No. 250."

TABLE VIII-4

BRAZOS RIVER BASIN POTABILITY SCALE

(mean concentration range mg/l)

Constituent	Excellent	Good	Fair	Poor	Unacceptable
TDS	<300	300<650	650<1000	1000<1300	>1300
$Cl+SO_4$	<200	200<500	500< 650	650< 800	> 800
Cl	<100	100<250	250< 300	300< 400	> 400

recommended upper limits, however, as a matter of practicality it will not be engineeringly feasible or economically sound to provide this quality supply throughout the Basin. Therefore, it is necessary to establish measures of acceptability. The scale in Table VIII-4 is such a measuring device.

Quality Improvements

Man-made degradation of water resources in the Brazos River Basin was discussed in Chapter VII. Active state programs already exist to deal with this problem, therefore, it is sufficient to say that significant progress has been made and it is reasonable to expect that by the year 2020 man-made degradation will be properly controlled and the affect of historic man-made degradation will be erased or reduced to tolerable levels.

A system is now needed to deal with degradation of water resources in the Brazos River Basin by natural phenomena such as brine emissions and solution of minerals from rocks and soil. It is apparent with little study that it will not be feasible to attempt to improve the quality of every stream in the basin, however, the quality of runoff collected in the main stem of the Brazos River can be improved by various alternative procedures. Large quantities of high quality (low mineral concentration) water could theoretically be imported and released into the Brazos River to regulate its quality. Poor quality (high mineral concentration) runoff could be collected, stored and evaporated or it could be transported by pipeline for disposal in the Gulf of Mexico or processed through a desalinization plant for supplying local water demands. All of these alternatives were considered but lake surface evaporation was judged to be most feasible.

After the most feasible method of control was selected it was necessary to design a project that would provide the desired degree of quality control. Unfortunately, no project was discovered that would improve the quality of water resources collected in the main stem of the Brazos River to meet our initial objective; the quality of main stem resources could not be improved to such a degree that they would meet the 1962 U. S. Public Health Service Drinking Water Standards one-hundred percent of the time. It was possible, though, to produce supplies equal in quality to those already in use and favorably accepted in many areas throughout the United States.

The project described in Chapter III was formed after extensive tests of various combination of control structures and has been judged to be the most desirable design configuration.

Figures VIII-1, VIII-2, and VIII-3 graphically depict the projected quality of water resources in the main stem of the Brazos River after Plan 4A salinity control project (Figure III-2) is in place and the year 2020 water supply and waste water return flow plan (Appendix II) is operating. The graphs do not reflect improvements in quality conditions that will accrue from reduction of pollution from oil production. Graphs are shown on each figure to describe the quality condition expected at five locations - USGS (stream gage and quality) Station No. 825 Brazos River at Seymour, Texas; USGS (stream gage) Station No. 890 Brazos River near Palo Pinto 20 miles downstream from Possum Kingdom Dam; USGS (stream gage) Station No. 965 Brazos River at Waco, Texas, 2 1/2 miles downstream from the Bosque River; USGS (stream gage and quality) Station No. 1090 Brazos River near Bryan, Texas; USGS (stream gage and quality) Station No. 1140 Brazos River at Richmond, Texas, river mile 93. Table VIII-5 presents values excerpted from the graphs and predictions of future quality conditions.

If the quality of water expected at Station No. 825 is measured with the potability scale (Table VIII-4), the quality would range from fair to unacceptable and would be unacceptable approximately 50 percent of the time, poor approximately 20 percent of the time and fair only 30 percent of the time. Development of municipal supplies at this point would not be recommended. The quality would be acceptable for other uses such as selective use for irrigation, livestock watering and mining.

At Station No. 890 the quality will range from Good to Fair, is Fair approximately 60 percent of the time and Good approximately 40 percent of the time. Satisfactory municipal supplies could be withdrawn at this point. The quality compares favorably with municipal

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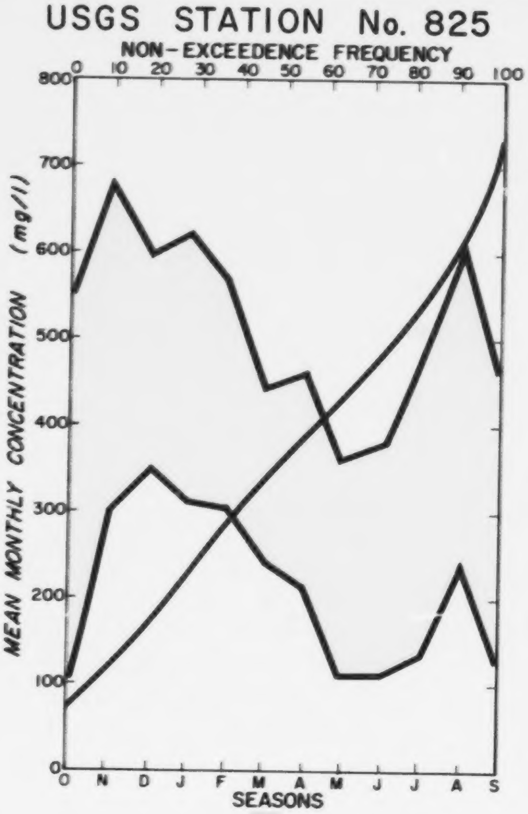

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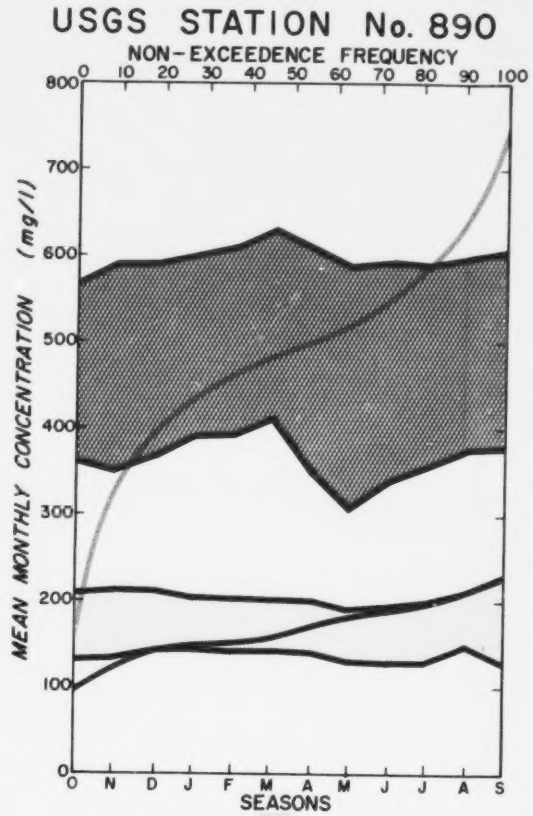
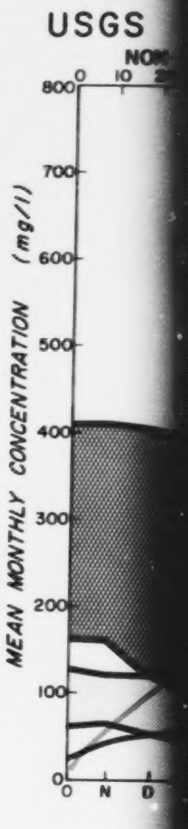


USGS STATION No. 890



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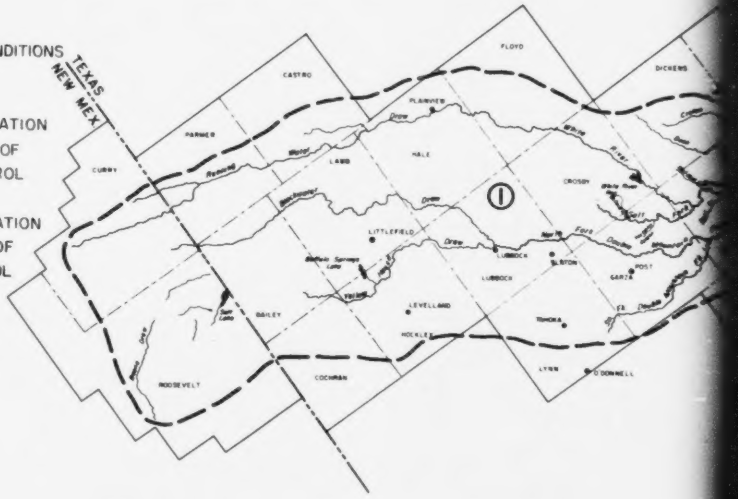
─ NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 1962 BASIN DEVELOPMENT WITHOUT SALT CONTROL

─ NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL

□ RANGE OF MEAN MONTHLY CONCENTRATIONS ONE STANDARD DEVIATION ABOVE AND BELOW THE MEAN CONCENTRATION FOR THE PERIOD OF RECORD ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL

▨ RANGE OF MEAN MONTHLY CONCENTRATIONS ONE STANDARD DEVIATION ABOVE AND BELOW THE MEAN CONCENTRATION FOR THE PERIOD OF RECORD WITH 1962 BASIN DEVELOPMENT WITHOUT SALT CONTROL



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NOTE: WATER YEARS 1941-62 STREAMFLOW RECORDS WERE USED FOR SIMULATION OF MATHEMATICAL MODEL FLOW

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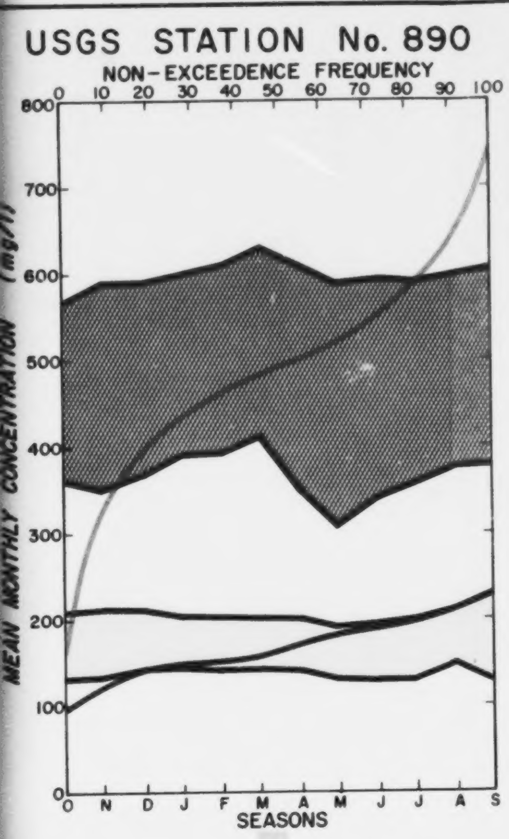
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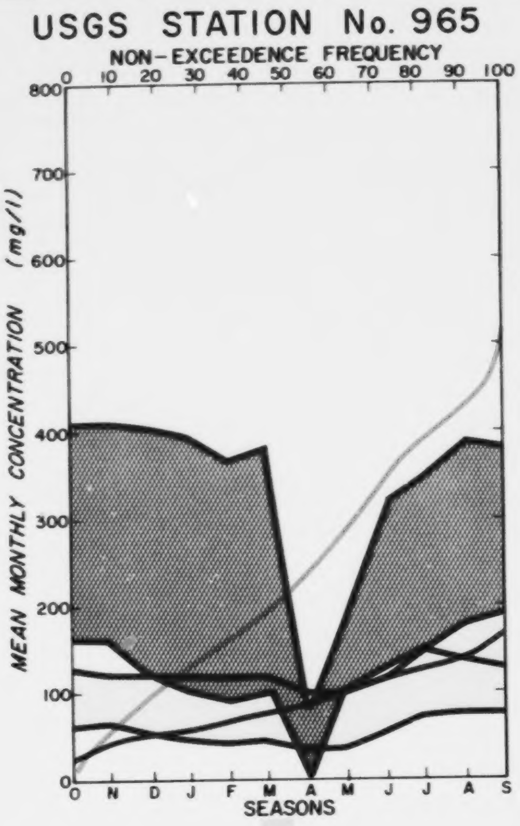
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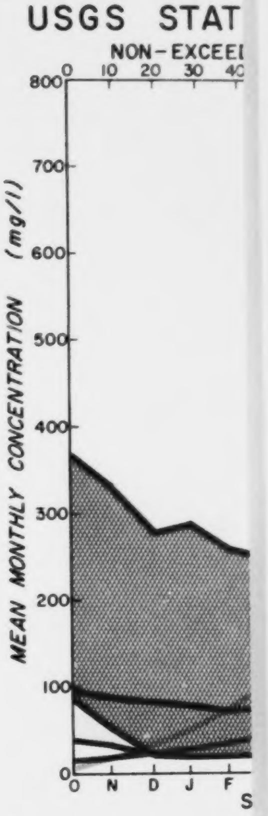
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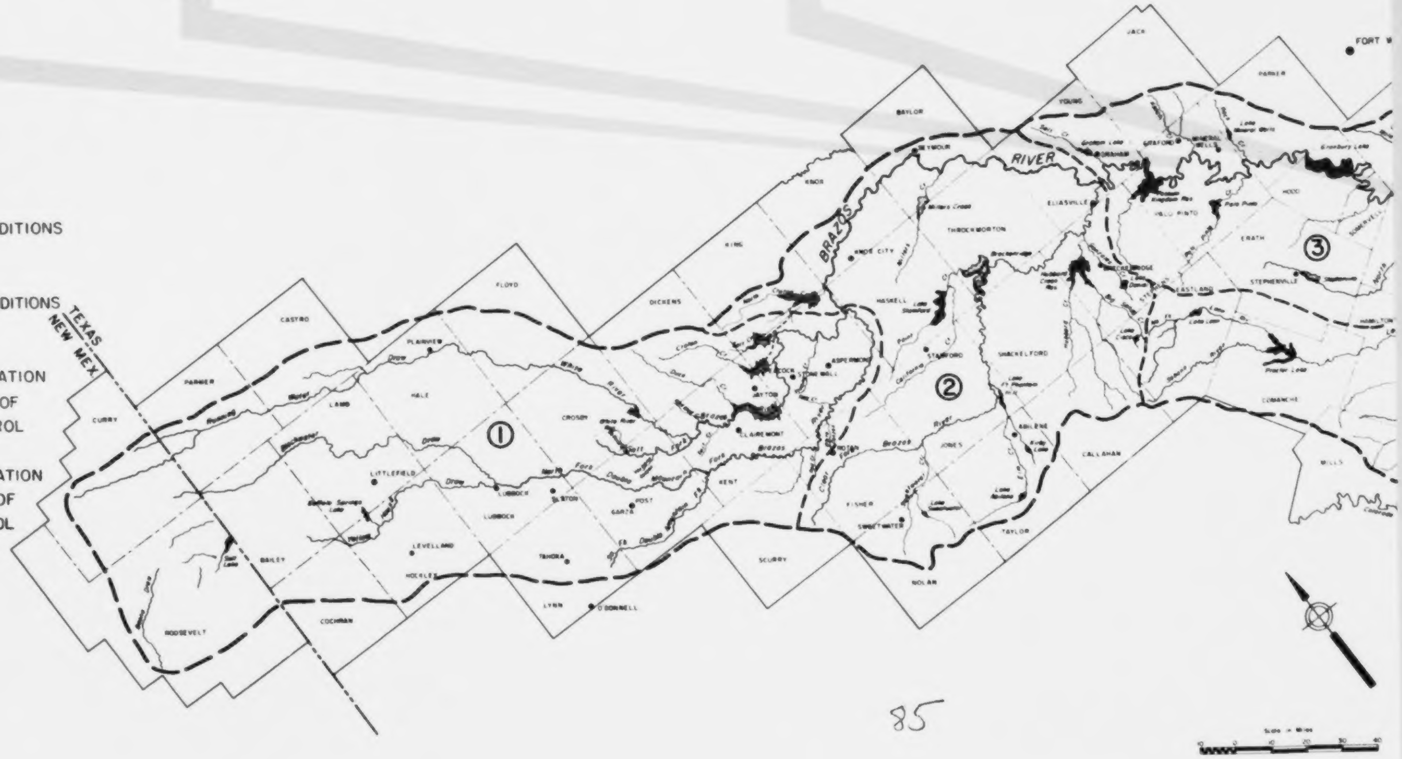
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CALLAHAN
THROCKMORTON
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KNOX CITY
ELIASVILLE
PALO PINTO
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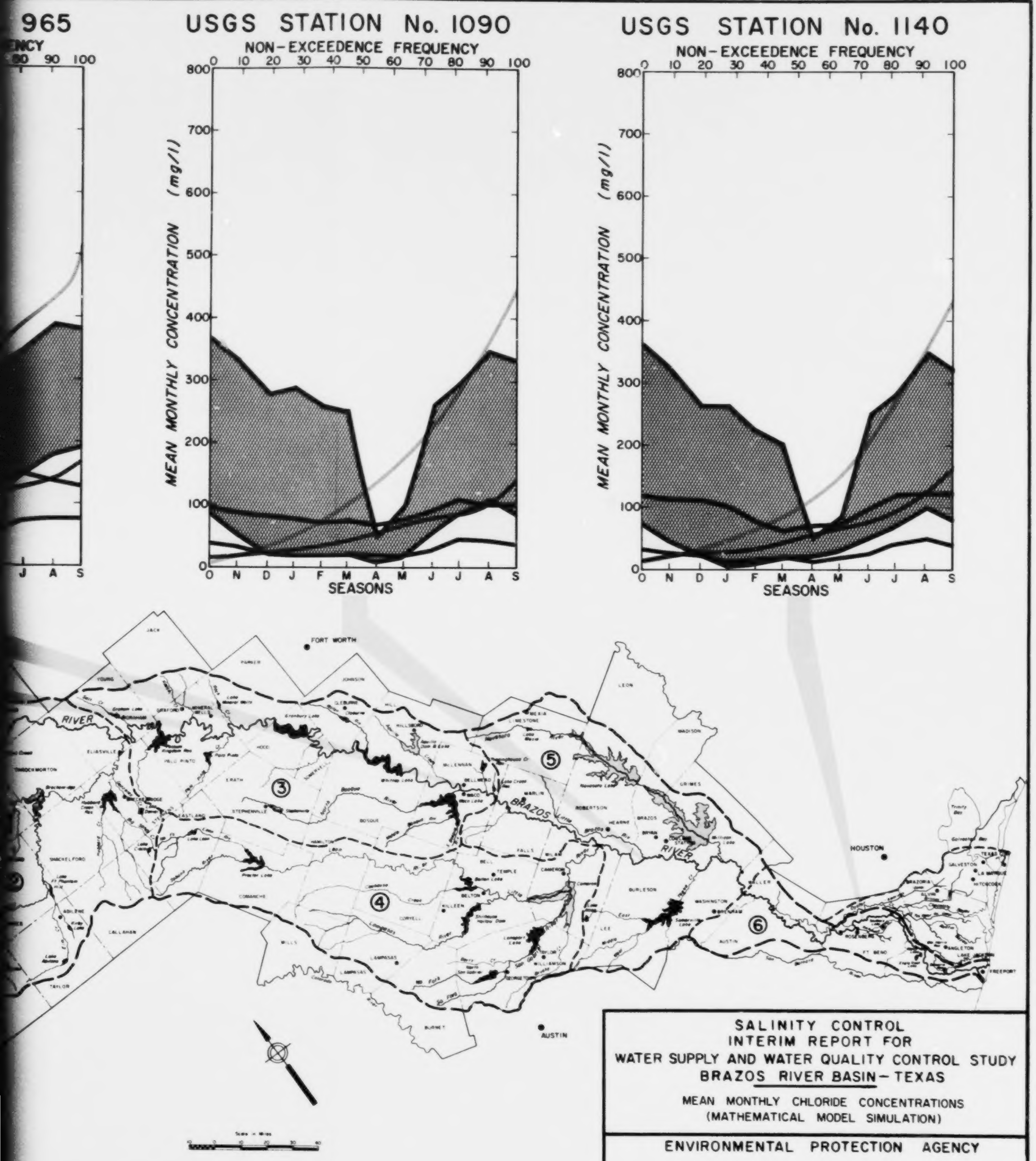

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

MEAN MONTHLY CHLORIDE CONCENTRATIONS
(MATHEMATICAL MODEL SIMULATION)

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE VIII-1

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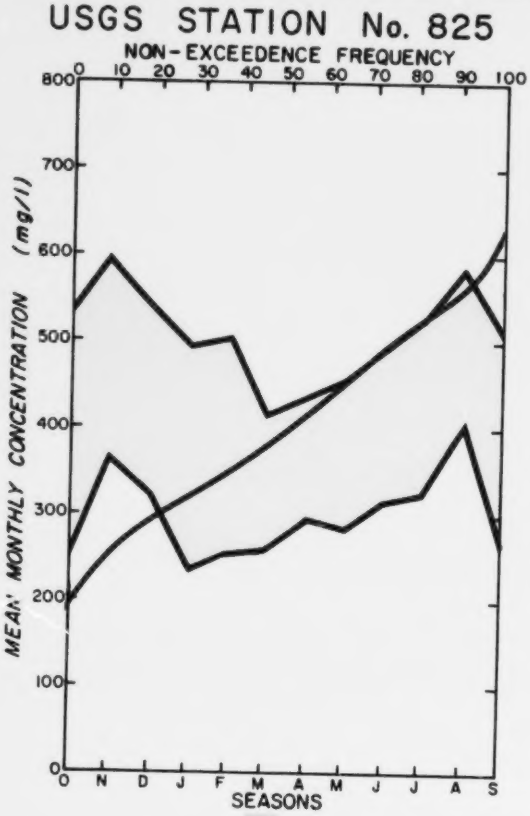
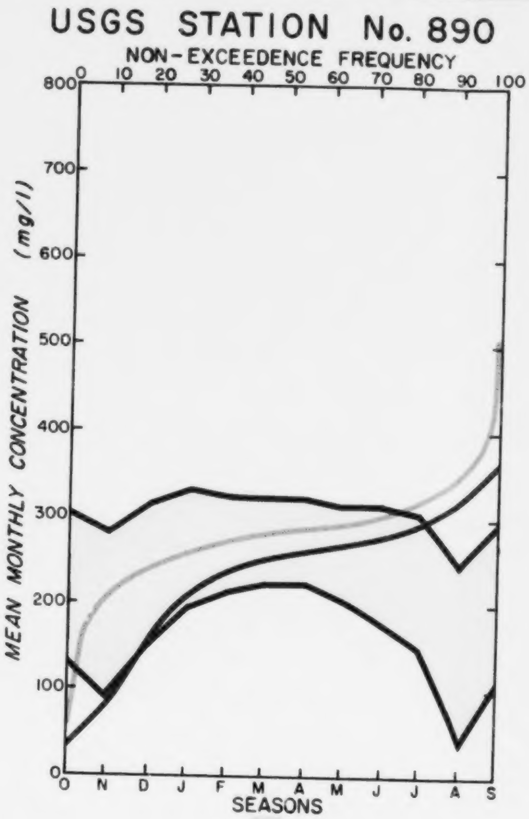
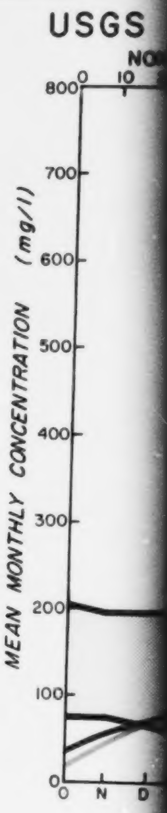




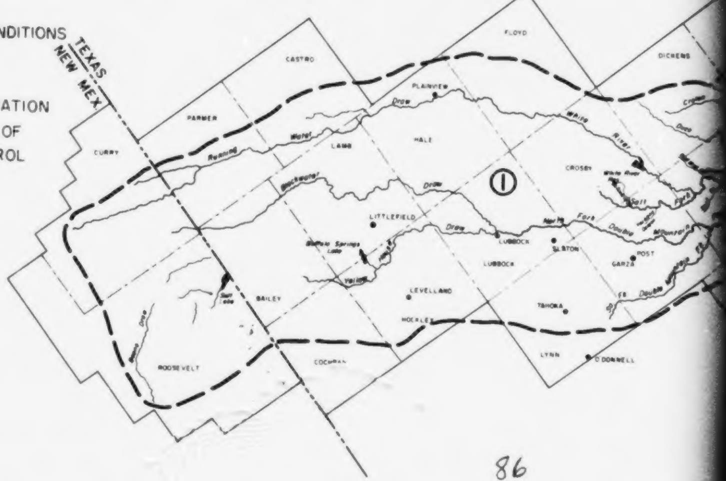


LEGEND

▭ NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 1962 BASIN DEVELOPMENT WITHOUT SALT CONTROL

▭ NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL

▭ RANGE OF MEAN MONTHLY CONCENTRATIONS ONE STANDARD DEVIATION ABOVE AND BELOW THE MEAN CONCENTRATION FOR THE PERIOD OF RECORD ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL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COCHRAN
LYNN
O'DONNELL
White River
Running Water Draw
Blackwater Draw
Yellow House Draw
Double Mountain Fork
North Fork Double Mountain

NOTE: WATER YEARS 1941-62 STREAMFLOW RECORDS WERE USED FOR SIMULATION OF MATHEMATICAL MODEL FLOW

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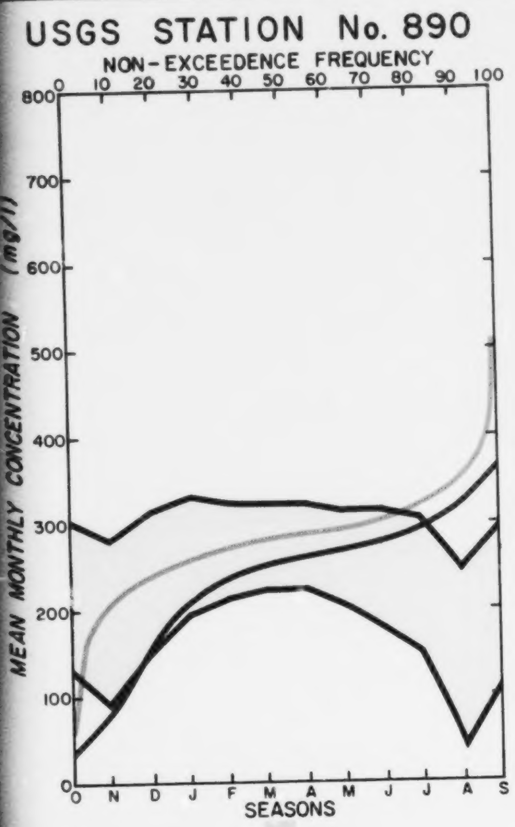

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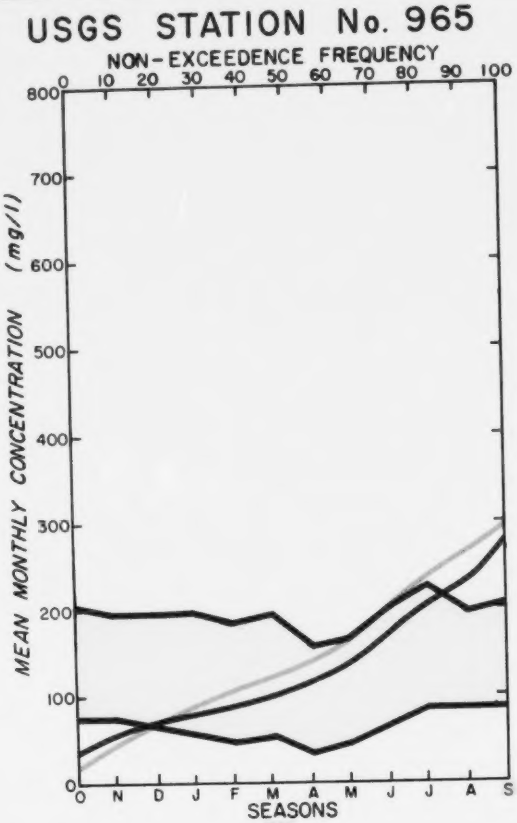

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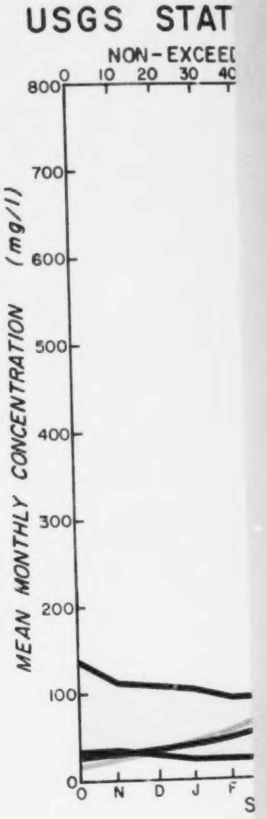

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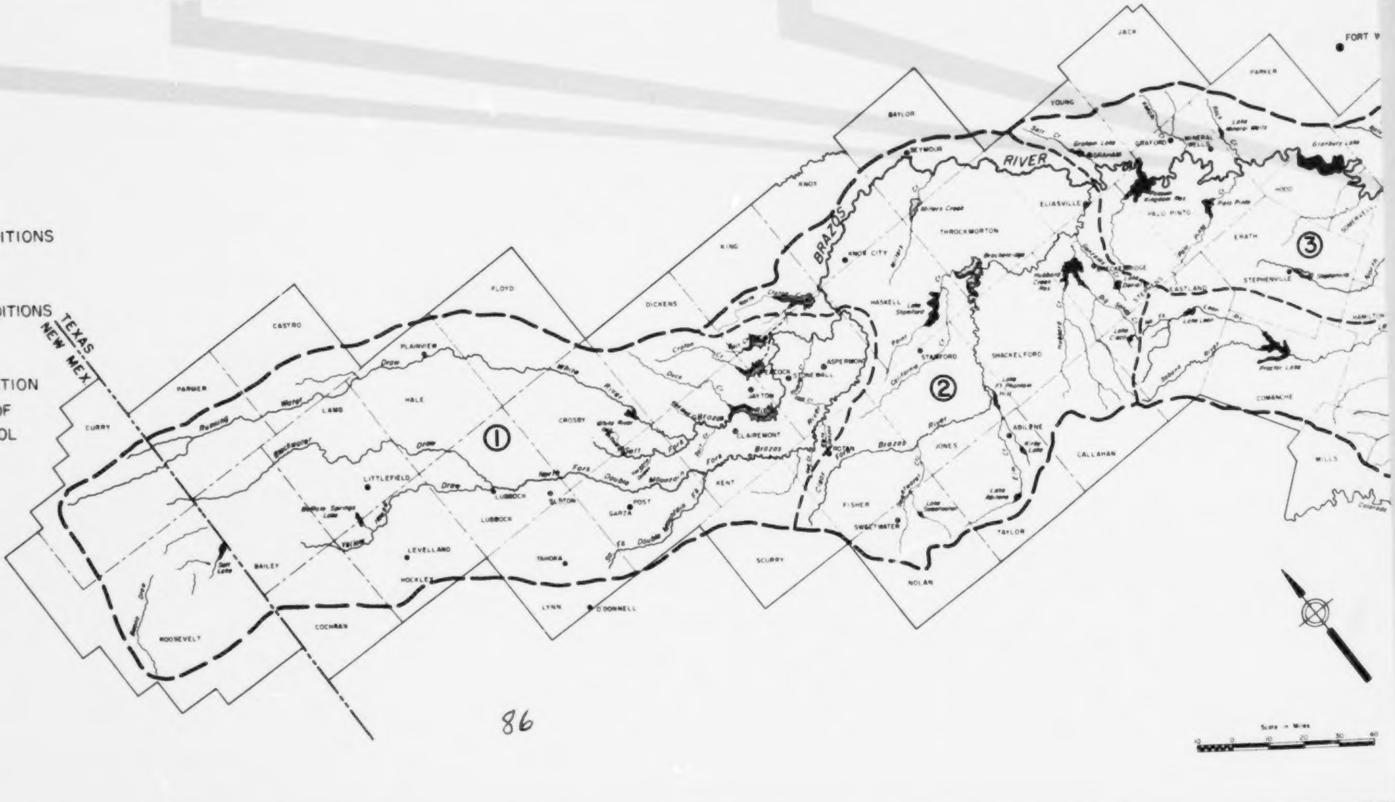

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FISHER
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JONES
TAYLOR
ABILENE
CALLAHAN
SHACKELFORD
HASKELL
STAMFORD
THROCKMORTON
KNOX CITY
ASPERMONT
SEYMOUR
ELIASVILLE
GRAFORD
MINERAL WELLS
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COMANCHE
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O'DONNELL
SLATON
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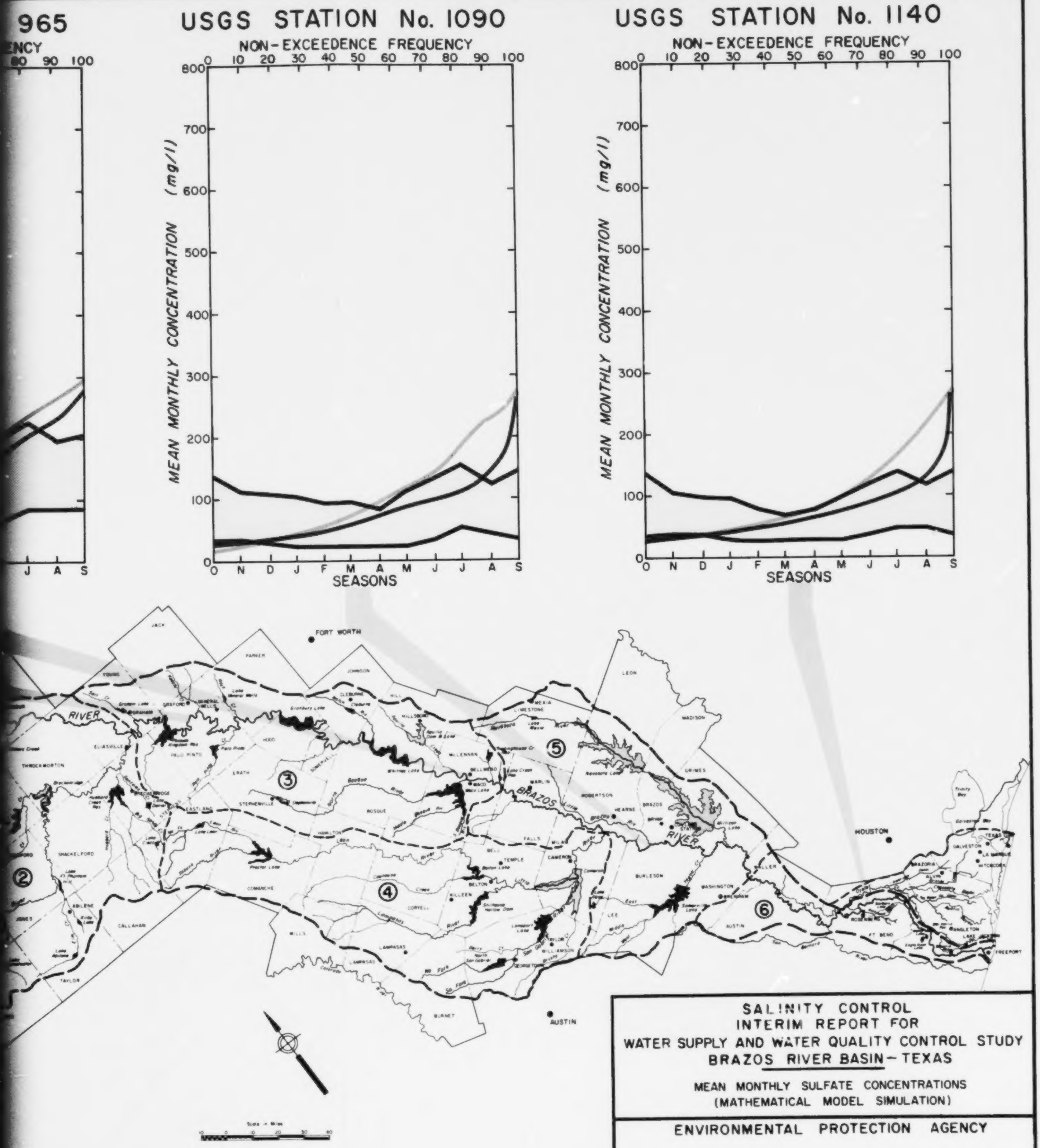


SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

MEAN MONTHLY SULFATE CONCENTRATIONS
(MATHEMATICAL MODEL SIMULATION)

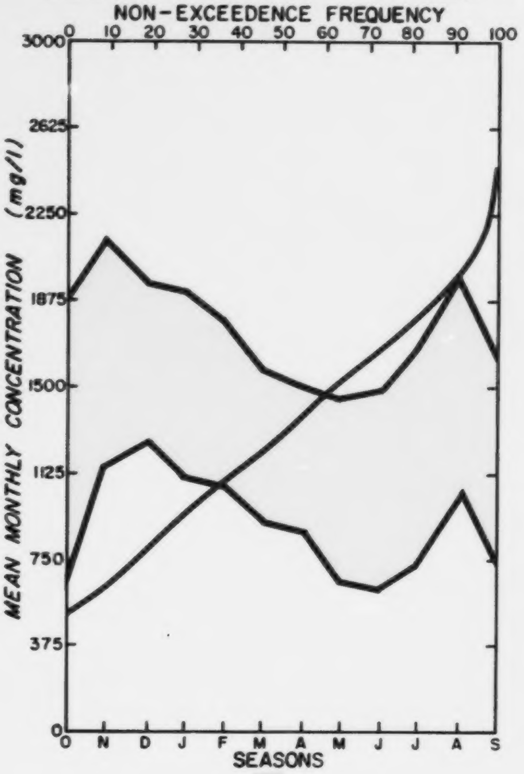
ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

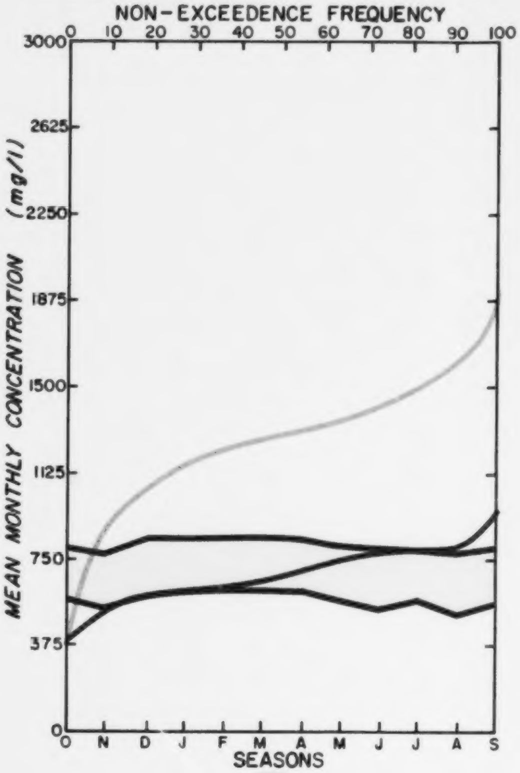
FIGURE VIII-2

A

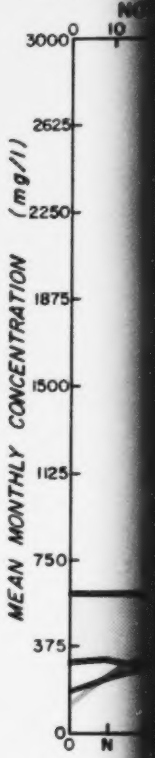
USGS STATION No. 825



USGS STATION No. 890



USGS

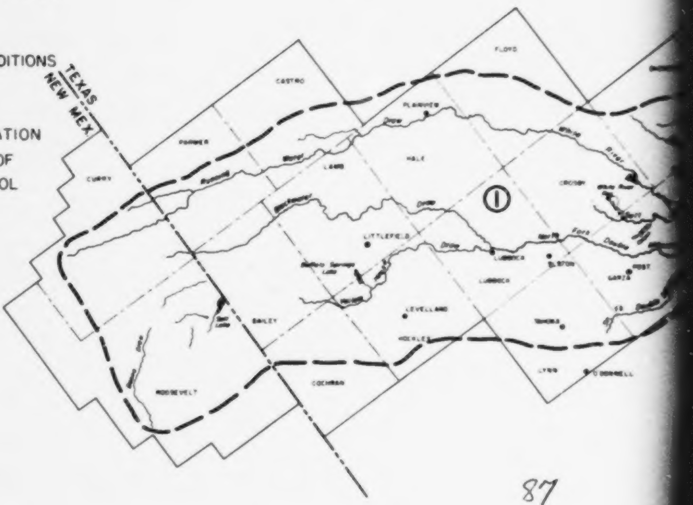


LEGEND

NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 1962 BASIN DEVELOPMENT WITHOUT SALT CONTROL

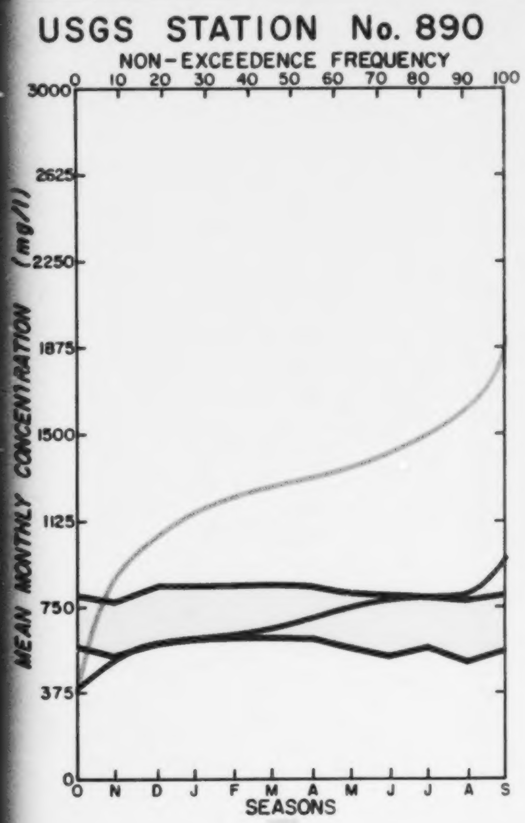
NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL

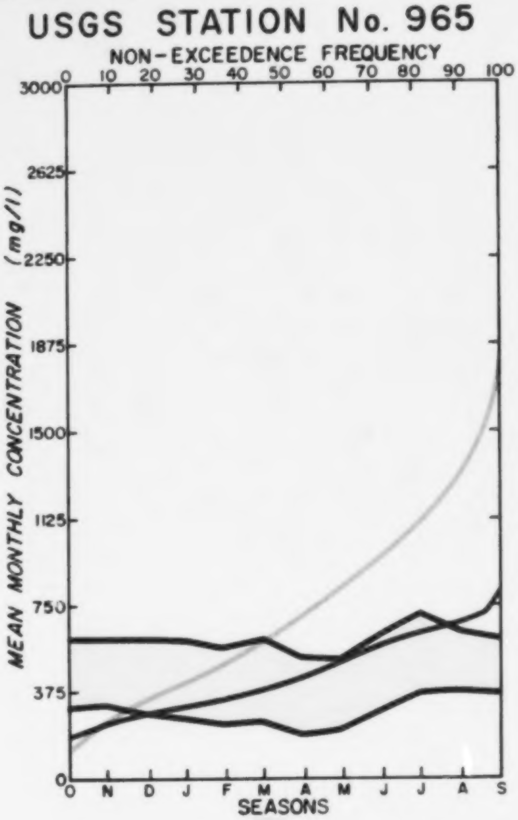
RANGE OF MEAN MONTHLY CONCENTRATIONS ONE STANDARD DEVIATION ABOVE AND BELOW THE MEAN CONCENTRATION FOR THE PERIOD OF RECORD ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL

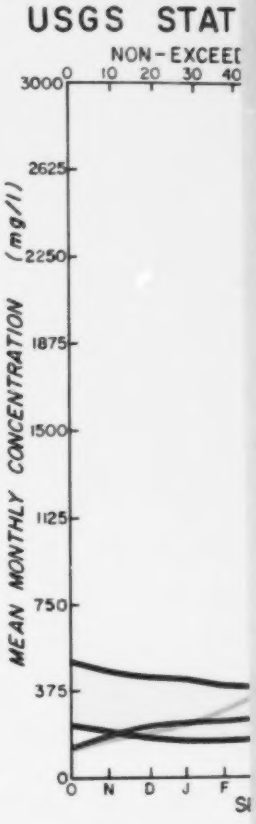

TEXAS
NEW MEX
CASTRO
FLOYD
PLAINVIEW
PARMER
LAMB
HALE
CURRY
①
CROSBY
LITTLEFIELD
LUBBOCK
LEVELLAND
HOCKLEY
BAILEY
COCHRAN
ROOSEVELT
LYNN

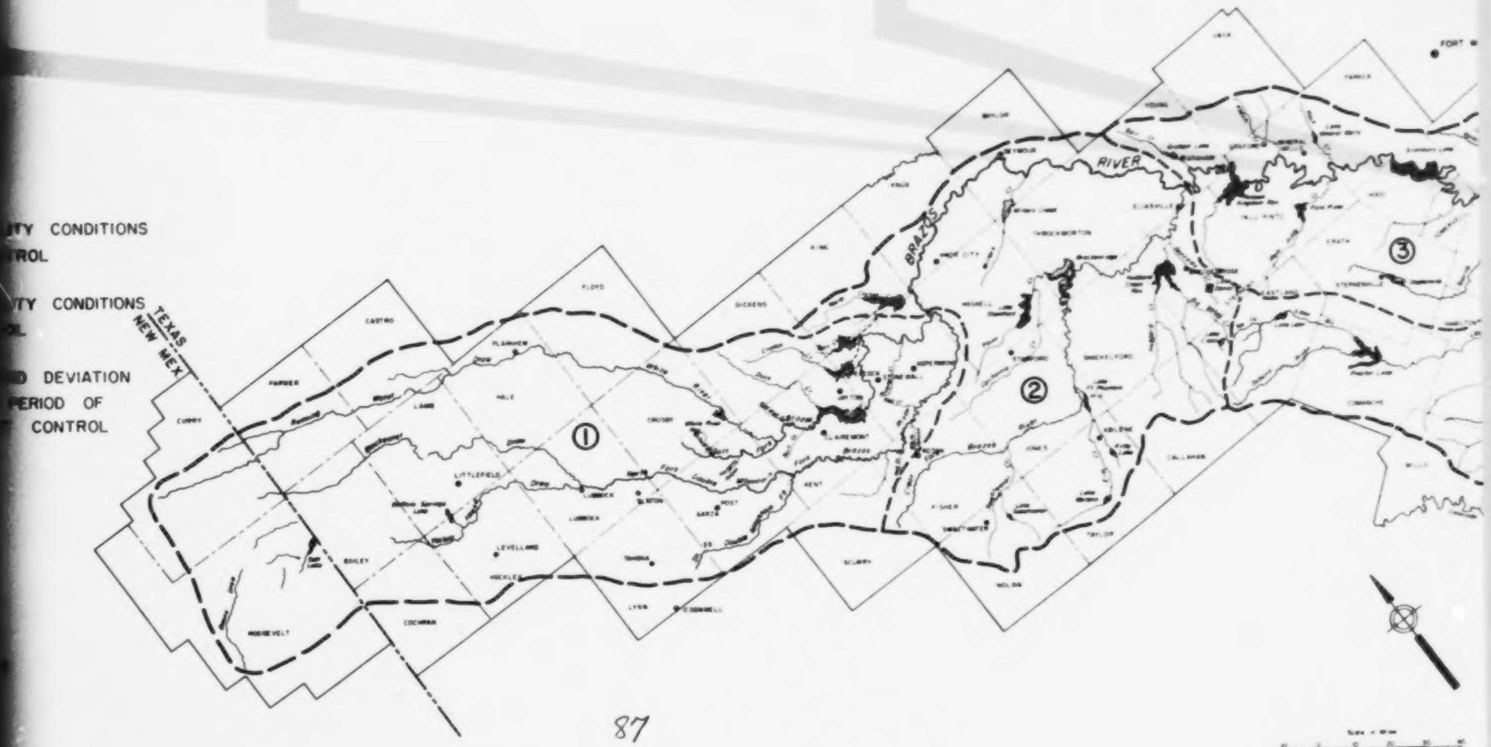
NOTE: WATER YEARS 1941-62 STREAMFLOW RECORDS WERE USED FOR SIMULATION OF MATHEMATICAL MODEL FLOW

B

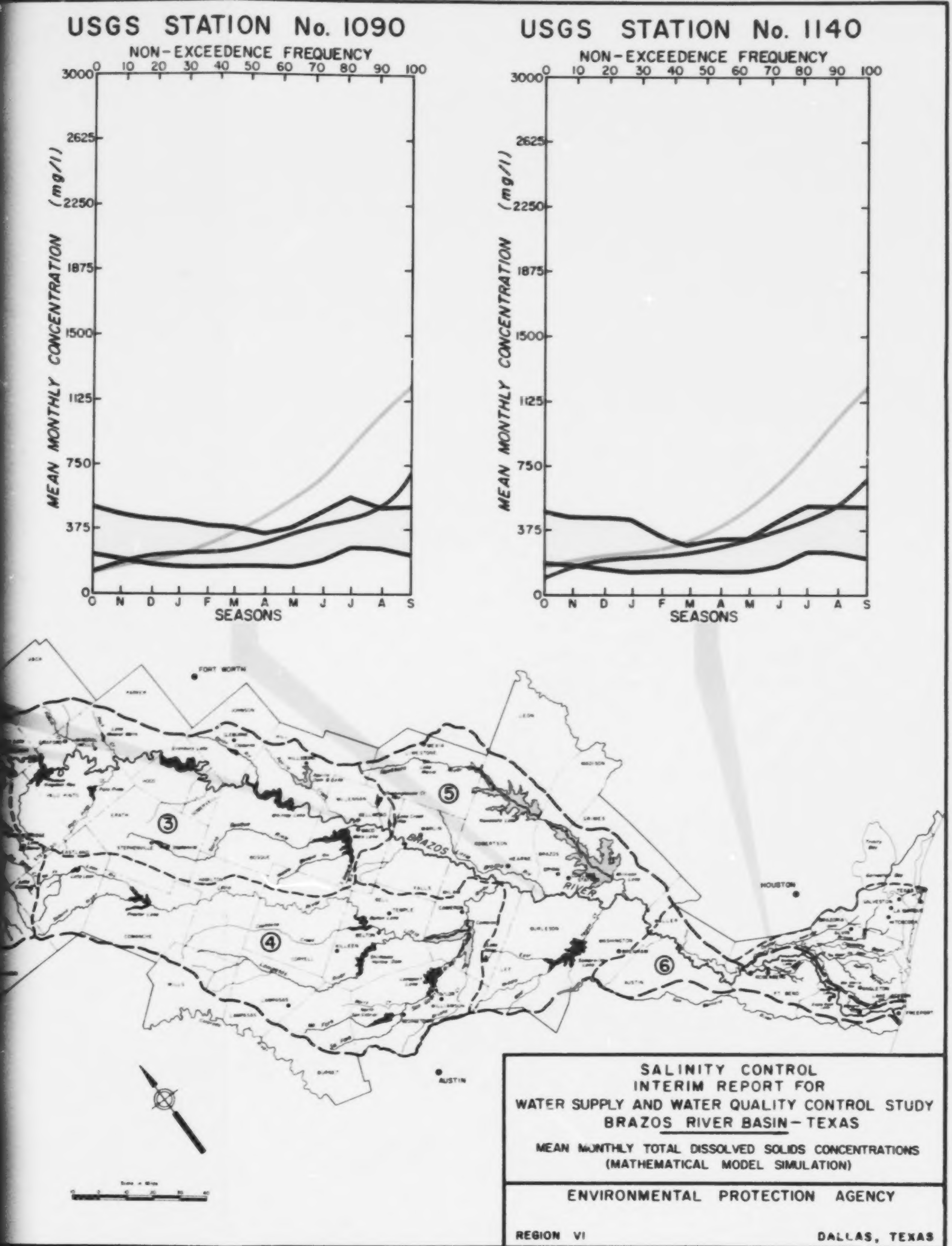

USGS STATION No. 890
NON-EXCEEDENCE FREQUENCY
0 10 20 30 40 50 60 70 80 90 100
MEAN MONTHLY CONCENTRATION (mg/l)
3000
2625
2250
1875
1500
1125
750
375
0
O N D J F M A M J J A S
SEASONS


USGS STATION No. 965
NON-EXCEEDENCE FREQUENCY
0 10 20 30 40 50 60 70 80 90 100
MEAN MONTHLY CONCENTRATION (mg/l)
3000
2625
2250
1875
1500
1125
750
375
0
O N D J F M A M J J A S
SEASONS


USGS STAT
NON-EXCEEI
0 10 20 30 40
MEAN MONTHLY CONCENTRATION (mg/l)
3000
2625
2250
1875
1500
1125
750
375
0
O N D J F
S


TY CONDITIONS
TROL
TY CONDITIONS
OL
D DEVIATION
ERIOD OF
CONTROL
TEXAS
NEW MEX
BRAZOS
RIVER
①
②
③
FORT W

87



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BRAZOS RIVER BASIN – TEXAS

MEAN MONTHLY TOTAL DISSOLVED SOLIDS CONCENTRATIONS
(MATHEMATICAL MODEL SIMULATION)

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE VIII-3

TABLE VIII-5

SURFACE WATER QUALITY PREDICTION

Station (Figure V-2)	Stream and Location	Quality Prediction (2020 Conditions) — Potability Scale Classification — % of Time Mean Monthly Concentration Will Be In Class: Excellent	Good	Fair	Poor	Unacceptable	Simulation Model Quality — Percent of Time Equaled or Exceeded — Mean Monthly Concentration (mg/l) (2020 Conditions With 1941-62 Runoff): 10	25	50	75	90
825	Brazos River at Seymour			30	20	50					
	Sulfate						555	500	395	310	255
	Chloride						600	500	370	210	125
	Dissolved Solids						1990	1705	1315	940	675
890	Brazos River near Palo Pinto		40	60							
	Sulfate						320	280	260	200	80
	Chloride						215	195	165	155	130
	Dissolved Solids						825	805	695	620	545
965	Brazos River at Waco	20	60	20							
	Sulfate						225	175	105	80	55
	Chloride						140	125	85	60	45
	Dissolved Solids						695	620	430	330	260
1090	Brazos River near Bryan	54	44	2							
	Sulfate						135	100	65	40	30
	Chloride						105	90	55	30	25
	Dissolved Solids						525	430	280	245	190
1140	Brazos River at Richmond	54	44	2							
	Sulfate						120	90	60	40	30
	Chloride						125	90	55	30	25
	Dissolved Solids						525	430	280	245	190

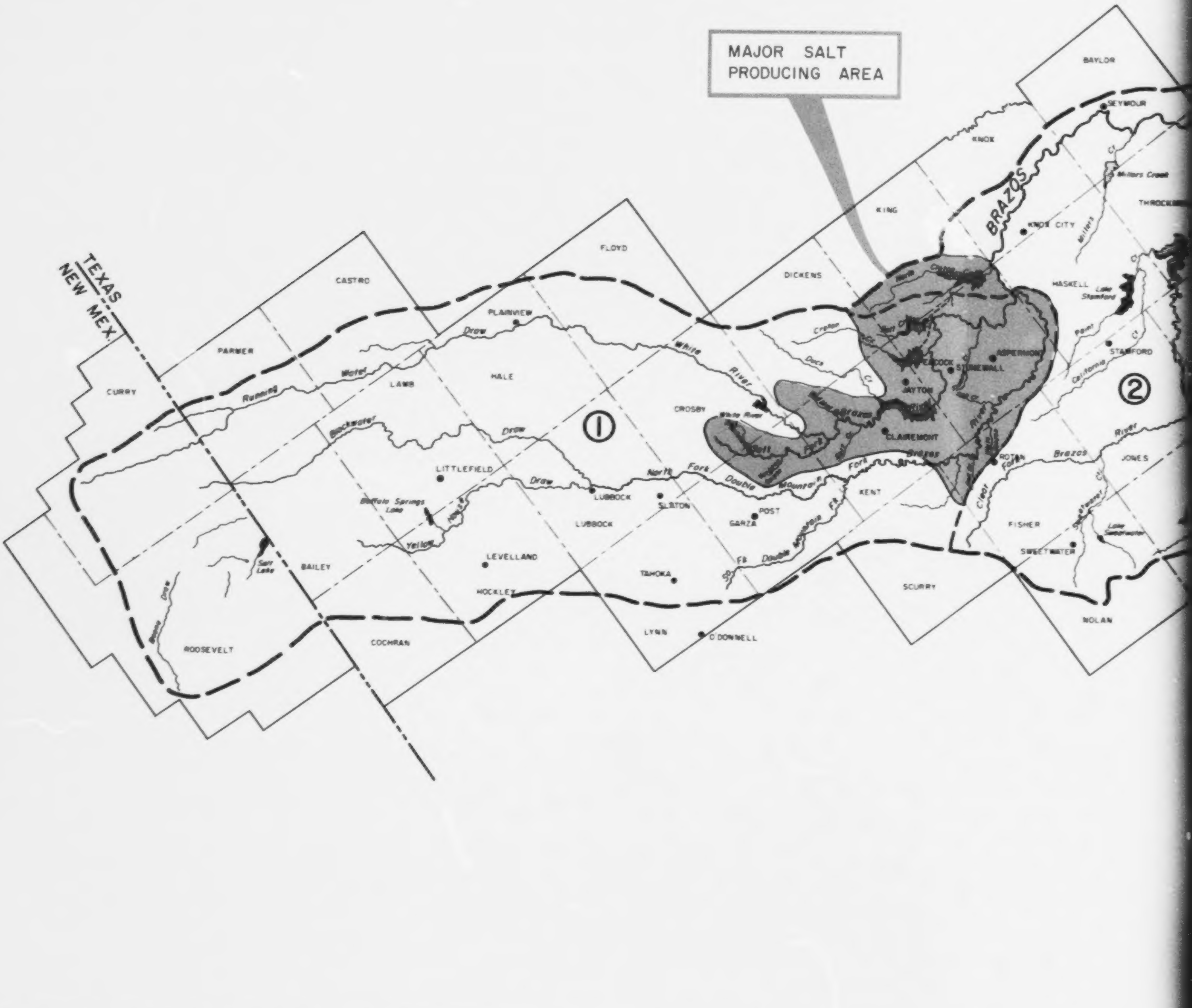
supplies currently in use in the general locality and in many municipal systems throughout the United States.

At Station No. 965 the quality will range from Excellent to Fair, is Fair approximately 20 percent of the time, Good approxiamtely 60 percent of the time and Excellent approximately 20 percent of the time. Municipal supplies withdrawn at this point would be very satisfactory. The quality compares favorably with municipal groundwater supplies currently used in the general locality, in fact, in many instances the Brazos River water would be more desirable than the groundwater supplies and would meet U. S. Public Health Service Drinking Water Standards - 1962 approximately 60 percent of the time.

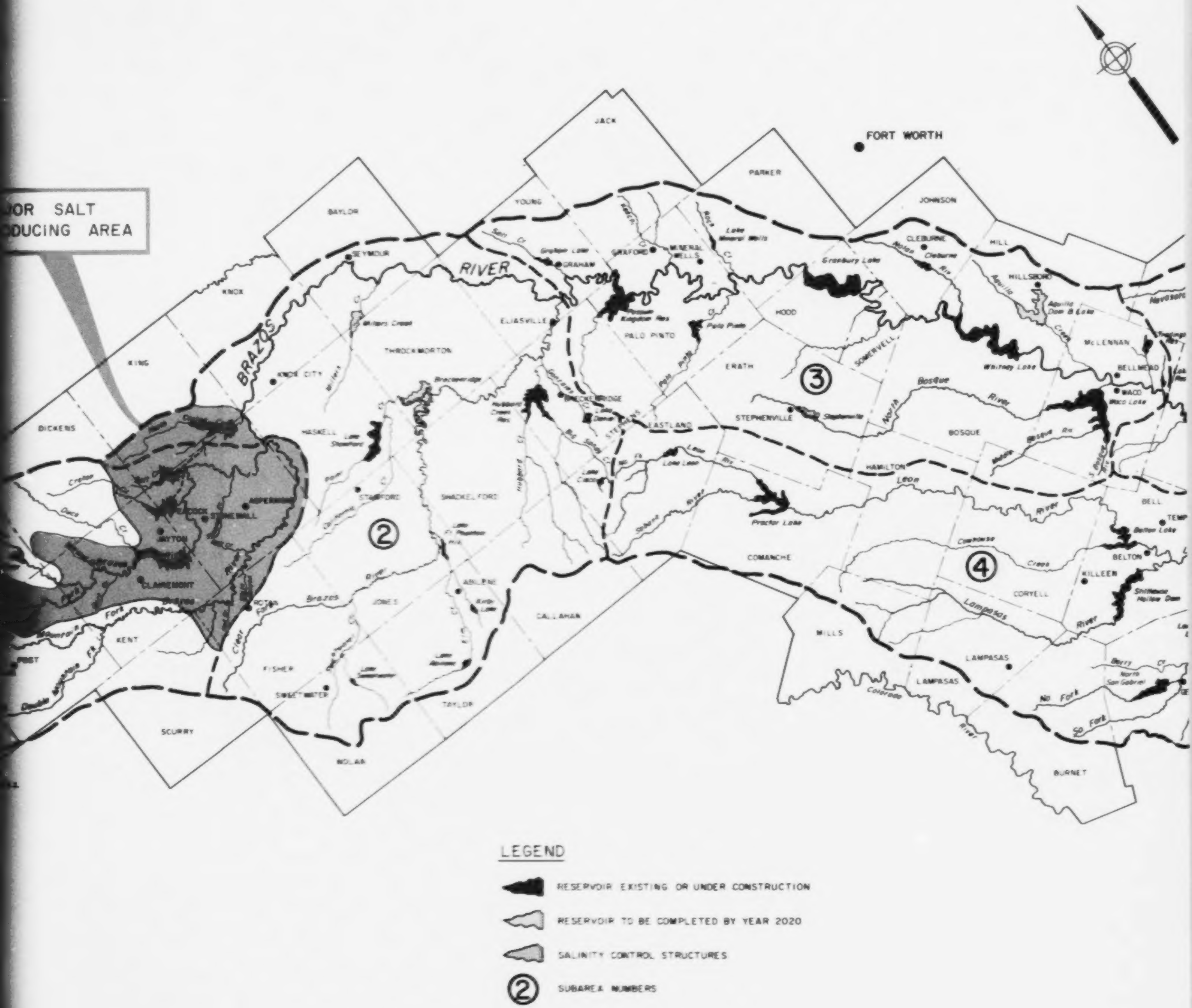
At Stations Nos. 1090 and 1140 the quality will range from Excellent to Fair, is Fair approximately 4 percent of the time, Good approximately 44 percent of the time and Excellent approximately 54 percent of the time. Municipal supplies withdrawn at these points would meet U. S. Public Health Service Drinking Water Standards - 1962 approximately 88 percent of the time.

It can be concluded from our study that construction of the proposed salinity control project (Plan 4A) will result in a substantial reduction of the degradation of main stem resources. Mineral quality improvements will allow full utilization of those resources. Brazos River Basin water resources transported in the main stem could be withdrawn at any point from Possum Kingdom reservoir to the mouth of the river for municipal water supplies.

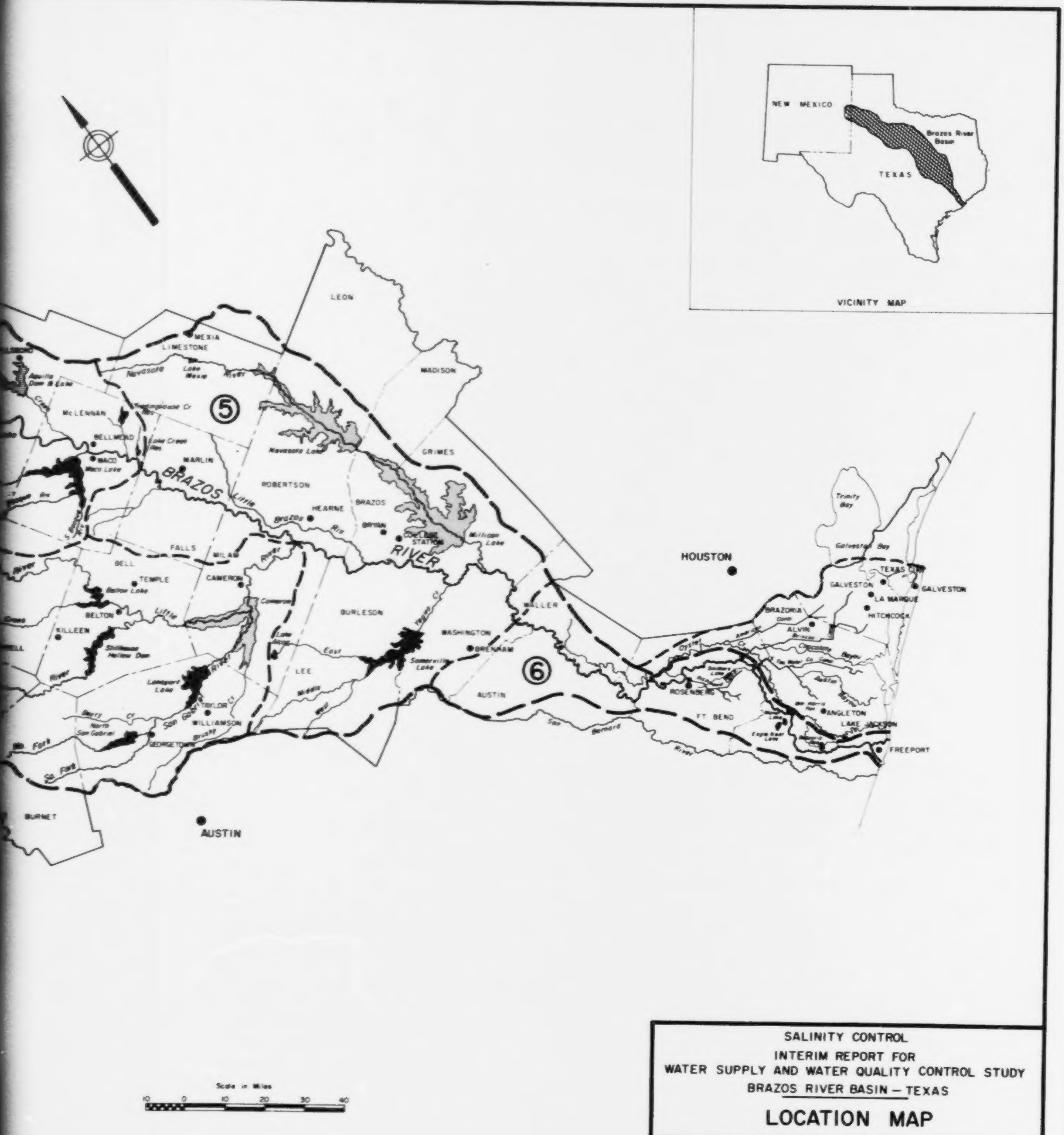
A


MAJOR SALT PRODUCING AREA
TEXAS
NEW MEX.
CURRY
PARMER
CASTRO
FLOYD
LAMB
HALE
CROSBY
DICKENS
KING
KNOX
BAYLOR
THROCK
HASKELL
STAMFORD
JONES
FISHER
KENT
SCURRY
NOLAN
GARZA
LYNN
LUBBOCK
HOCKLEY
COCHRAN
BAILEY
ROOSEVELT
PLAINVIEW
LITTLEFIELD
LEVELLAND
SLATON
POST
TAHOKA
O'DONNELL
JAYTON
PEACOCK
STONEWALL
ASPERMONT
CLAIREMONT
ROTAN
SWEETWATER
SEYMOUR
KNOX CITY
BRAZOS
Running Water Draw
Blackwater Draw
Yellow House Draw
Buffalo Springs Lake
Salt Lake
White River
North Fork Double Mountain Fork
Double Mountain Fk.
Croton Cr.
Duck Cr.
Salt Cr.
Salt Fork Brazos
Brazos River
Clear Fork
California Cr.
Paint Cr.
Lake Stamford
Millers Creek
Lake Sweetwater
Sweetwater Cr.
①
②

B


JOR SALT
ODUCING AREA
FORT WORTH
JACK
PARKER
JOHNSON
BAYLOR
YOUNG
KNOX
KING
DICKENS
HILL
BRAZOS
RIVER
SEYMOUR
Graham Lake
GRAHAM
GRAFORD
MINERAL WELLS
Lake Mineral Wells
Granbury Lake
CLEBURNE
HILLSBORO
Aquilla Dam & Lake
ELIASVILLE
Millers Creek
THROCKMORTON
Possum Kingdom Res
PALO PINTO
Palo Pinto
HOOD
ERATH
SOMERVELL
Whitney Lake
McLENNAN
BELLMEAD
WACO
Waco Lake
KNOX CITY
Breckenridge
Hubbard Creek Res
BRECKENRIDGE
STEPHENS
EASTLAND
STEPHENVILLE
North Bosque River
BOSQUE
HASKELL
Lake Stamford
STAMFORD
SHACKELFORD
Lake Cisco
Lake Leon
Leon River
HAMILTON
Proctor Lake
COMANCHE
ASPERMONT
STONEWALL
JAYTON
CLAIREMONT
KENT
POST
Double Mountain Fk.
ROTAN
Clear Fork Brazos
FISHER
SWEETWATER
SCURRY
NOLAN
TAYLOR
JONES
ABILENE
CALLAHAN
MILLS
LAMPASAS
Lampasas River
Colorado River
BURNET
Cowhouse Creek
CORYELL
KILLEEN
BELTON
Belton Lake
Stillhouse Hollow Dam
BELL
TEMPLE
North San Gabriel
No Fork
So Fork
② ③ ④
LEGEND
RESERVOIR EXISTING OR UNDER CONSTRUCTION
RESERVOIR TO BE COMPLETED BY YEAR 2020
SALINITY CONTROL STRUCTURES
② SUBAREA NUMBERS

C


NEW MEXICO
TEXAS
Brazos River Basin
VICINITY MAP
LEON
MADISON
LIMESTONE
MEXIA
Navasota
Lake Mexia
River
Aquilla Dam & Lake
McLENNAN
BELLMEAD
WACO
Waco Lake
Lake Creek Res.
MARLIN
⑤
Navasota Lake
GRIMES
ROBERTSON
BRAZOS
Little
Brazos
Rio
HEARNE
BRAZOS
BRYAN
COLLEGE STATION
Millican Lake
RIVER
FALLS
MILAM
BELL
TEMPLE
Belton Lake
CAMERON
BELTON
Little
River
KILLEEN
Stillhouse Hollow Dam
Cameron
BURLESON
WASHINGTON
BRENHAM
Somerville Lake
Yegua Cr.
East
Middle
LEE
⑥
AUSTIN
WALLER
Laneport Lake
San Gabriel River
TAYLOR
WILLIAMSON
North San Gabriel
GEORGETOWN
Brushy
So. Fork
BURNET
AUSTIN
HOUSTON
Trinity Bay
Galveston Bay
TEXAS CITY
GALVESTON
LA MARQUE
GALVESTON
HITCHCOCK
BRAZORIA
ALVIN
Oyster Cr.
Chocolate Bayou
ROSENBERG
FT. BEND
Austin Bayou
ANGLETON
LAKE JACKSON
San Bernard
River
FREEPORT
Scale in Miles
10
0
10
20
30
40

SALINITY CONTROL
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BRAZOS RIVER BASIN – TEXAS

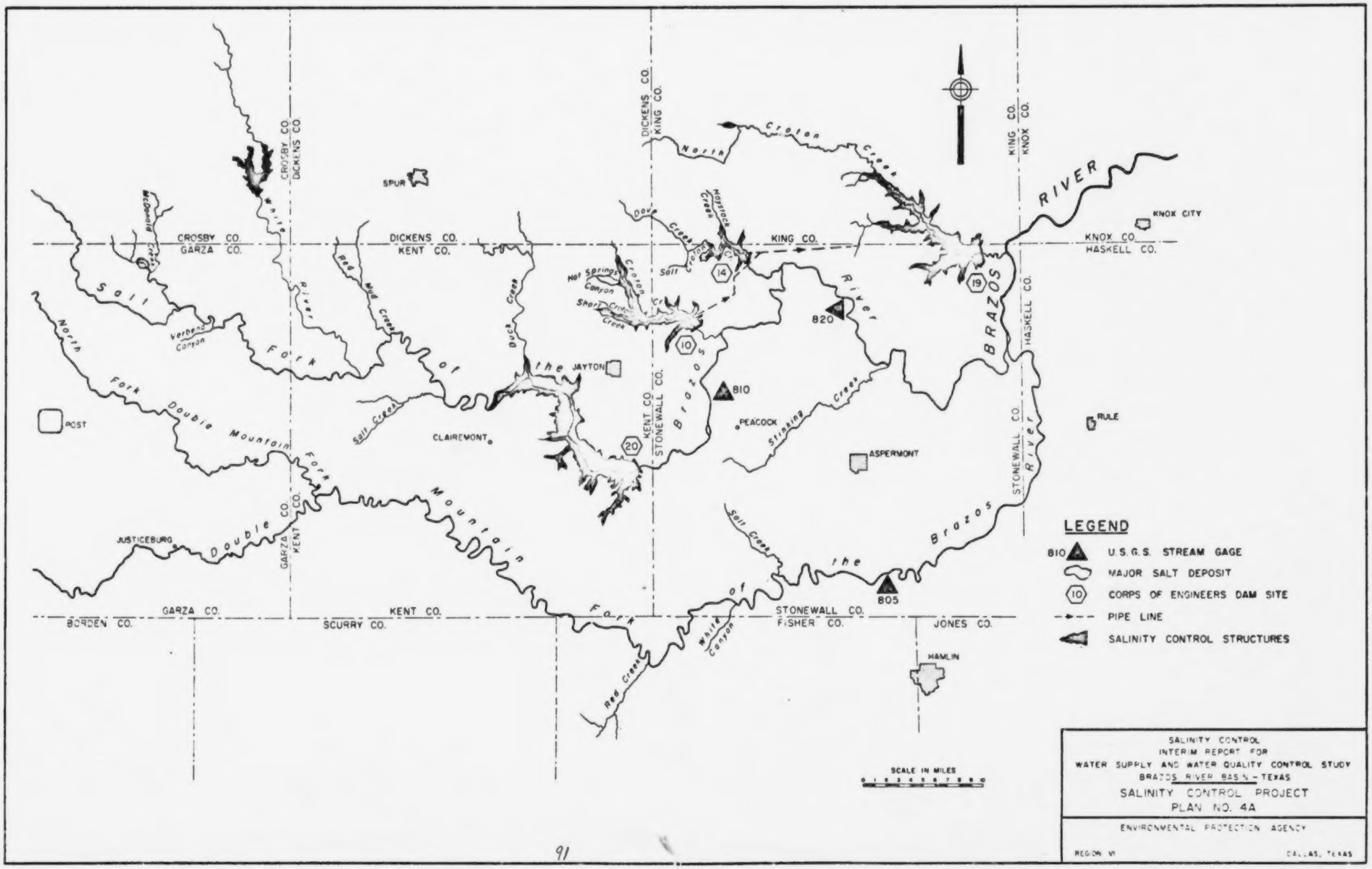
LOCATION MAP

ENVIRONMENTAL PROTECTION AGENCY

REGION VI

DALLAS, TEXAS

FIGURE III-1


CROSBY CO.
DICKENS CO.
DICKENS CO.
KING CO.
KING CO.
KNOX CO.
SPUR
KNOX CITY
CROSBY CO.
GARZA CO.
DICKENS CO.
KENT CO.
KING CO.
KNOX CO.
HASKELL CO.
McDonald Creek
White River
Red Mud Creek
Duck Creek
North Croton Creek
Croton Creek
Dove Creek
Haystack Creek
Salt Croton Creek
Hot Springs Canyon
Short Croton Creek
RIVER
BRAZOS
River
19
14
10
20
820
810
805
Salt Fork of the Brazos
Verbena Canyon
North Fork Double Mountain Fork
JAYTON
POST
CLAIREMONT
KENT CO.
STONEWALL CO.
PEACOCK
Stinking Creek
ASPERMONT
HASKELL CO.
STONEWALL CO.
River
RULE
Salt Creek
Double Mountain Fork of the Brazos
GARZA CO.
KENT CO.
JUSTICEBURG
Double
GARZA CO.
BORDEN CO.
KENT CO.
SCURRY CO.
STONEWALL CO.
FISHER CO.
JONES CO.
White Canyon
Red Creek
HAMLIN
LEGEND
810 U.S.G.S. STREAM GAGE
MAJOR SALT DEPOSIT
10 CORPS OF ENGINEERS DAM SITE
PIPE LINE
SALINITY CONTROL STRUCTURES
SCALE IN MILES
0 1 2 3 4 5 6 7 8 9 10

SALINITY CONTROL
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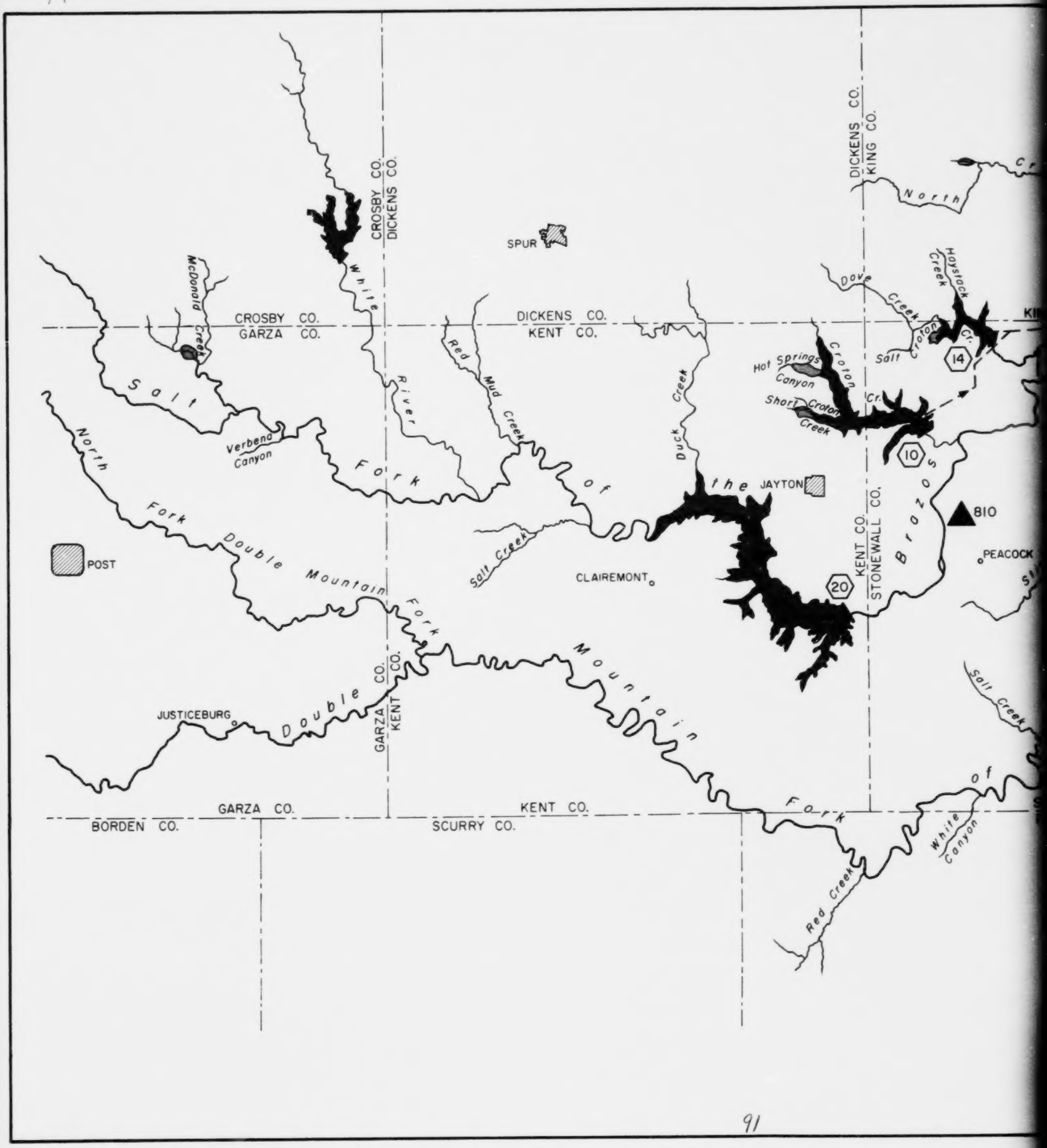
BRAZOS RIVER BASIN - TEXAS
SALINITY CONTROL PROJECT
PLAN NO. 4A

ENVIRONMENTAL PROTECTION AGENCY

REGION VI
DALLAS, TEXAS

FIGURE III-2

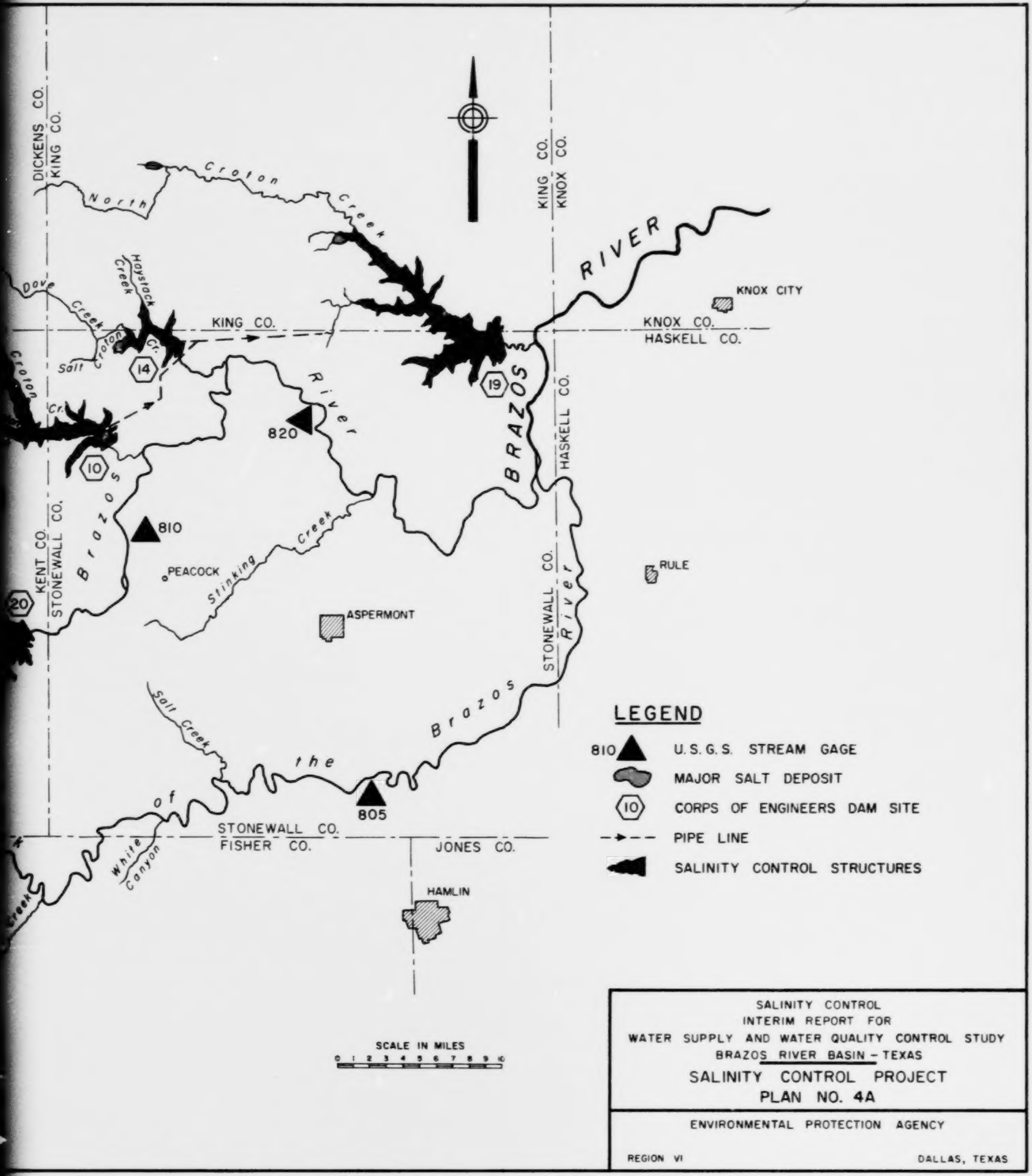
A



CROSBY CO.
DICKENS CO.
DICKENS CO.
KING CO.
Cr
North
SPUR
McDonald Creek
White
Dove Creek
Haystock Creek
KIN
CROSBY CO.
GARZA CO.
DICKENS CO.
KENT CO.
Red Mud Creek
Croton
Salt Croton
Cr.
14
Hot Springs Canyon
Salt
River
Duck Creek
Short Croton Creek
Cr.
Verbena Canyon
Salt
Fork
of
the
JAYTON
10
Brazos
North Fork Double Mountain Fork
810
POST
Salt Creek
PEACOCK
CLAIREMONT
20
KENT CO.
STONEWALL CO.
Fork
Mountain
GARZA CO.
KENT CO.
JUSTICEBURG
Double
Salt Creek
Fork
of
GARZA CO.
BORDEN CO.
KENT CO.
SCURRY CO.
White Canyon
Red Creek

91

B


DICKENS CO.
KING CO.
KING CO.
KNOX CO.
North
Croton
Creek
RIVER
Dove
Creek
Haystack
Creek
Croton
Cr.
Salt
Croton
Cr.
KING CO.
KNOX CITY
KNOX CO.
HASKELL CO.
14
19
River
BRAZOS
820
10
HASKELL CO.
Brazos
810
Stinking
Creek
PEACOCK
KENT CO.
STONEWALL CO.
20
RULE
ASPERMONT
STONEWALL CO.
River
Salt Creek
Brazos
the
of
805
STONEWALL CO.
FISHER CO.
JONES CO.
White
Canyon
Creek
HAMLIN
LEGEND
810 U. S. G. S. STREAM GAGE
MAJOR SALT DEPOSIT
10 CORPS OF ENGINEERS DAM SITE
PIPE LINE
SALINITY CONTROL STRUCTURES
SCALE IN MILES
0 1 2 3 4 5 6 7 8 9 10

SALINITY CONTROL
INTERIM REPORT FOR
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BRAZOS RIVER BASIN – TEXAS

SALINITY CONTROL PROJECT
PLAN NO. 4A

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE III-2

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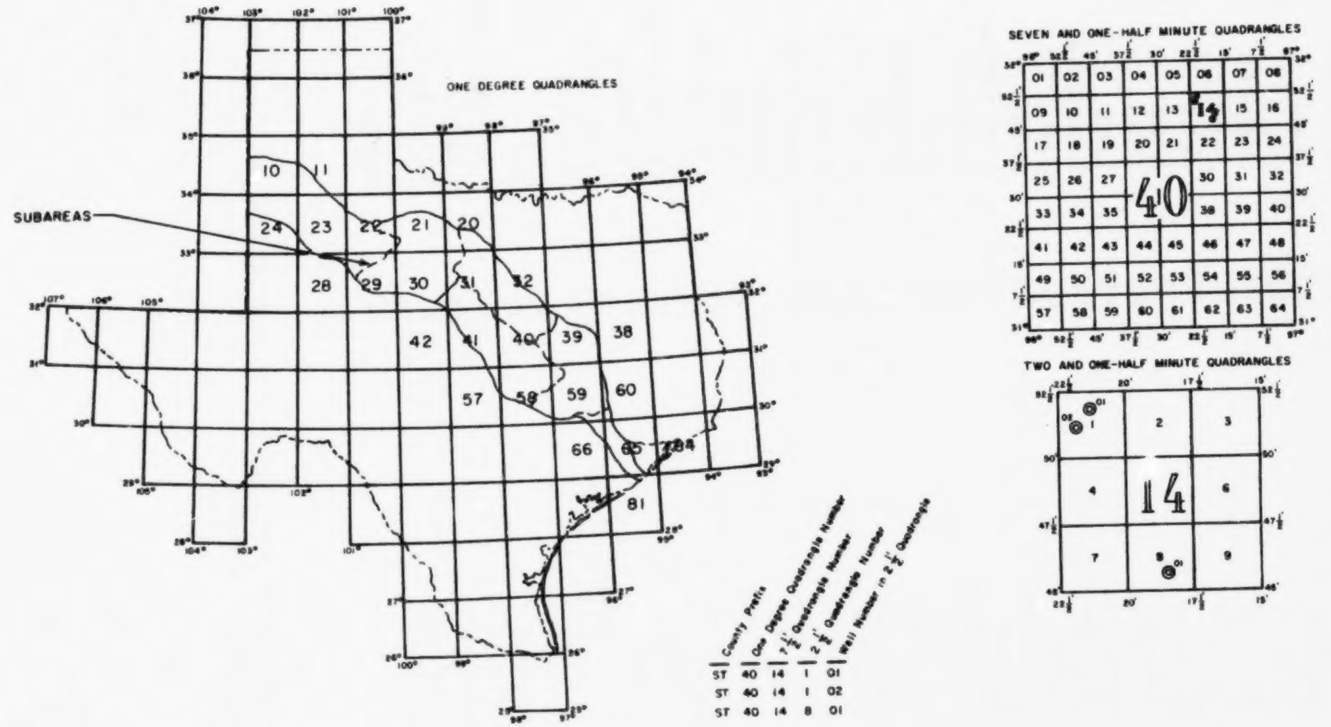
APPENDIX I

GROUNDWATER QUALITY ANALYSES

Well-Numbering System 1/

The numbers assigned to wells and springs in this report conform to the statewide system used by the Texas Water Commission. The system is based on the division of Texas into 1-degree quadrangles bounded by lines of latitude and longitude. Each 1-degree quadrangle is divided into 64 smaller quadrangles, 7-1/2 minutes on a side, each of which is further divided into 9 quadrangles, 2-1/2 minutes on a side. Each of the 89 1-Degree quadrangles in the State has been assigned a 2-digit number for identification (Figure AI-1). The 7-1/2 minute quadrangles are numbered with 2-digit numbers consecutively from left to right beginning in the upper left-hand corner of the 1-degree quadrangle, and the 2-1/2 minute quadrangles within each 7-1/2 minute quadrangle are similarly numbered with a 1-digit number. Each well inventoried in each 2-1/2 minute quadrangle is assigned a 2-digit number. The well number is determined as follows: From left to right, the first 2 numbers identify the 1-degree quadrangle, the next 2 numbers identify the 7-1/2 minute quadrangle, the fifth number identifies the 2-1/2 minute quadrangle, and the last 2 numbers designate the well in the 2-1/2 minute quadrangle.

In addition to the 7-digit well number, a 2-letter prefix is used to identify the county as follows:


ONE DEGREE QUADRANGLES
SUBAREAS
SEVEN AND ONE-HALF MINUTE QUADRANGLES
TWO AND ONE-HALF MINUTE QUADRANGLES
40
14
County Prefix
One Degree Quadrangle Number
7½' Quadrangle Number
2½' Quadrangle Number
Well Number in 2½' Quadrangle
ST 40 14 1 01
ST 40 14 1 02
ST 40 14 8 01

SOURCE:
TEXAS WATER COMMISSION
BULLETIN 6310
DECEMBER 1963

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN - TEXAS

WELL NUMBERING SYSTEM

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE AI - I

Prefix	County
AJ	Archer
AP	Austin
AR	Bailey
AT	Bastrop
AU	Baylor
AX	Bell
BA	Borden
BB	Bosque
BH	Brazoria
BJ	Brazos
BR	Brown
BS	Burleson
BT	Burnet
BX	Callahan
DD	Castro
DP	Cochran
DY	Comanche
HB	Coryell
HK	Crosby
HS	Dawson
HY	Dickens
JD	Eastland
JP	Erath
JR	Falls
JU	Fisher
JW	Floyd
JY	Fort Bend
KA	Freestone
KJ	Garza
KW	Grimes
KY	Hale
LA	Hamilton
LP	Haskell
LW	Hill
LX	Hockley
LY	Hood
PL	Jack
PX	Johnson
PY	Jones
RH	Kent
RL	King
RS	Knox
RU	Lamb
RW	Lampasas
RZ	Lee
SA	Leon
SD	Limestone
SP	Lubbock
SR	Lynn
ST	McLennan
TK	Milam
TL	Mills
UA	Nolan
UK	Palo Pinto
UP	Parker
UR	Parmer
WK	Robertson
WZ	Scurry
XA	Shackelford
XL	Stephens
XR	Stonewall
XT	Swisher
XW	Taylor
XY	Terry
XZ	Throckmorton
YW	Waller
YY	Washington
ZK	Williamson
ZU	Young

Groundwater quality analyses are presented in the following Tables AI-1 and AI-2.

TABLE A1-1

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							OGALLALA								
AR-10-41-901	140	June 17, 1955	46	0.00	62	46	35	8.6	211	140	70	2.4	4.9	551	344
AR-24-09-601	206	Apr. 11, 1961	30	--	43	25	55	6.4	222	80	42	3.0	7.5	403	210
DD-10-30-503	423	Oct. 18, 1960	60	.08	32	28	48	7.2	293	34	15	2.8	1.2	374	195
DP-24-12-701	217	Apr. 11, 1961	38	--	33	41	55	8.6	280	85	38	3.4	3.8	444	251
DP-25-24-301	178	May 24, 1961	59	--	124	50	131[c]		196	422	136	2.2	2.0	1,020	515
HK-23-20-605	--	Oct. 17, 1960	42	.22	41	35	37	11	330	34	15	2.5	3.8	383	246
HK-23-23-703	304	Oct. 17, 1960	39	.07	38	31	61	10	351	38	16	3.0	4.5	414	222
HK-23-31-401	325	May 16, 1961	40	--	39	31	74	9.1	382	43	20	3.6	5.9	454	225
JW-11-53-401	268	June 16, 1955	60	.03	45	37	42	10	352	40	22	2.4	1.1	432	264
JW-23-06-501	368	Apr. 17, 1961	50	--	38	38	34	8.6	346	29	12	2.6	4.0	391	252
KI-23-44-801	140	May 17, 1960	50	--	36	52	78	11	325	97	82	--	6.6	582	304
KY-11-49-501	200	June 22, 1955	59	.20	48	32	19	7.7	307	21	16	2.6	4.3	366	252
KY-23-10-101	267	Oct. 17, 1960	47	--	96	74	52	15	364	162	142	1.8	3.5	780	544
LX-24-21-801	241	Apr. 11, 1961	43	--	34	47	71	12	310	117	44	4.3	4.0	533	278
LK-24-[illegible]0-601	170	Aug. 15, 1956	52	.00	48	56	64	12	343	141	51	4.8	1.5	599	351
RU-10-33-301	200	Oct. 18, 1960	31	.04	41	28	30	7.0	276	28	16	1.8	8.4	334	218
RU-19-63-601	250	June 21, 1955	58	.02	66	24	22	5.8	296	28	26	1.1	12	389	263
RU-24-05-701	54	June 5, 1952	30	--	70	145	298[c]		293	632	350	8.0	7.2	1,680	770
SP-23-17-101	170	Aug. 14, 1956	63	.00	95	98	140	17	298	464	165	1.6	.8	1,190	640
SP-24032-902	207	Oct. 17, 1960	50	.04	28	44	93	12	357	88	49	5.8	3.0	550	251
SR-23-43-401	151	Oct. 17, 1960	52	.08	46	48	117	12	346	142	91	4.9	9.7	712	312
SR-28-02-204	40	Aug. 10, 1949	48	--	206	200	299[c]		217	743	620	--	11	2,160	1,340
TR-09-40-901	318	Apr. 12, 1961	35	.03	30	26	30	6.6	226	28	19	2.9	9.8	300	182
TR-10-35-901	400	June 17, 1955	33	.03	42	22	24	7.7	263	20	10	1.9	7.4	300	195

See footnotes at end of table

Source: Texas Water Commission Bulletin 6310

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
						QUATERNARY ALLUVIUM (OSAGE PLAINS)									
AU-21-22-804	41	Aug. 8, 1961	31	--	45	58	269[c]		540	164	205	--	42	1,080	351
21-29-302	27	do	24	--	70	33	125	5.2	424	101	2	1.1	51	681	310
21-30-302	45	Jan. 13, 1961	30	0.01[d]	71	62	431	5.2	540	394	350	--	42	1,650	432
HY-22-25-302[e]	83	June 4, 1960	27	.03	74	22	81	1.7	312	86	68	1.0	17	538	275
22-25-902	63	May 16, 1961	19	--	80	125	712	5.5	566	932	560	--	84	2,800	714
22-34-105[e]	46	June 9, 1961	27	.02[d]	80	45	270	1.1	300	366	218	3.6	56	1,220	384
JU-29-13-101	25	Aug. 4, 1960	25	--	585	33	39[c]		120	1,390	16	--	139	2,290	1,600
29-13-601	50	do	36	--	675	161	752[c]		220	2,040	1,140	--	86	5,000	2,350
29-14-901	36	do	22	--	94	29	336[c]		332	446	225	--	37	1,350	354
29-23-102	30	Aug. 8, 1960	23	--	530	146	743[c]		322	1,940	870	.7	32	4,440	1,920
29-23-603	34	do	24	--	2 3	59	420[c]		322	734	460	.8	58	2,140	812
KJ-23-46-201	24	May 29, 1961	37	--	72	56	879	3.3	664	724	650	2.6	131	2,880	410
23-55-801	22	do	13	--	64	31	684[c]		254	212	950	2.0	.0	2,080	287
LP-21-35-701	70	Sept. 1, 1956	26	--	81	27	120	5.9	336	99	103	1.0	54	684	312
21-42-101	60	Aug. 16, 1956	32	--	71	38	202	--	215	248	200	--	68	1,020	334
21-42-401[e]	54	Mar. 24, 1944	21	.14	75	17	109	5.2	333	59	43	.6	129	623	257
21-49-101[f]	48	Aug. 9, 1961	14	--	715	188	871	11	238	2,300	1,320	.6	46	5,580	2,560
LP-21-49-601[g]	45	Mar. 21, 1944	21	.05	91	24	114	6.6	362	57	73	.4	152	627	326
21-50-601	50	Aug. 16, 1956	30	--	130	61	217	--	311	255	322	--	75	1,240	575
21-51-701[e]	32	Mar. 17, 1944	21	.02	151	92	221	10	399	251	365	1.2	177	1,490	756
PY-30-17-101	32	July 9, 1953	38	.00[d]	90	16	13[c]		298	20	12	1.8	40	374	290
30-18-401	69	June 22, 1953	42	--	140	25	109	--	552	80	100	.6	8.2	776	452
30-19-401	46	July 6, 1953	30	--	144	34	176	--	576	109	215	1.0	2.0	994	500

See footnotes at end of table

Source: Texas Water Commission Bulletin 6310

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a/] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3) b/	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Hard-ness as $CaCO_3$
QUATERNARY ALLUVIUM (OSAGE PLAINS) (Continued)															
PY-30-19-402	60	June 18, 1953	47	--	146	27	176	4.9	545	130	200	0.2	22	1,020	476
RH-22-41-801	72	May 16, 1961	23	--	525	162	530	7.9	234	2,390	345	--	2.5	4,100	1,980
22-43-203	102	June 21, 1960	45	--	358	60	44c/		194	898	88	.8	19	1,610	1,140
22-43-503	98	d0	47	--	301	53	132c/		344	590	225	.7	51	1,570	970
22-43-504	136	June 22, 1960	--	--	--	--	--	--	--	344	88	--	40	--	--
22-43-505	126	June 21, 1960	52	--	288	44	121c/		308	610	168	.5	47	1,480	900
22-43-508	110	do	24	--	203	45	85c/		236	514	88	.7	26	1,100	692
33-51-104	44	May 16, 1961	21	--	655	217	1,280	11	158	2,760	1,680	--	40	6,750	2,530
22-52-102e/	52	June 21, 1960	25	--	252	42	85c/		249	578	112	.6	25	1,240	800
22-52-103e/	52	do	20	--	104	12	21c/		229	113	20	.5	25	436	309
22-52-104	62	do	21	--	96	8.9	3.0	5.9	214	86	5.2	.5	24	356	276
22-59-702f/	--	June 1, 1961	17	--	432	91	423c/		181	1,430	520	.8	.0	3,000	1,450
RS-21-33-901	50	Aug. 30, 1956	24	--	170	128	528	5.8	342	1,120	460	--	45	2,650	950
21-34-201	31	Aug. 15, 1956	34	--	59	35	97	--	323	106	50	--	63	618	292
21-34-501e/	35	Apr. 24, 1957	36	--	109	43	180c/		350	211	185	1.4	84	1,020	448
21-36-401e/	37	Mar. 22, 1944	21	0.12	112	99	372	15	481	469	340	1.9	183	1,780	686
21-36-401e/	37	Apr. 25, 1957	35	--	113	98	334c/		485	411	360	2.4	90	1,680	685
21-34-401f/	40	Aug. 30, 1956	19	--	229	53	628	6.4	322	853	740	--	1.9	2,690	790
XR-21-49-102	58	Aug. 9, 1961	24	--	46	16	86c/		321	43	16	.5	44	434	181
XR-22-45-801	59	May 22, 1961	17	--	695	176	605c/		84	2,020	1,130	.5	7.5	4,690	2,460
22-46-801	52	June 14, 1961	34	--	85	16	190c/		356	154	135	.2	58	854	278
XR-29-06-104f/	51	Aug. 10, 1961	18	--	525	138	933	9.0	190	1,600	1,480	1.1	7.5	4,810	1,880
XW-30-50-102	21	Aug. 4, 1960	24	--	100	36	94c/		282	114	115	--	111	796	398

See footnotes at end of table

Source: Texas Water Commission Bulletin 6310

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Screened Interval (feet)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							TRINITY GROUP								
AX-40-60-904	743-965[g]	May 25, 1954	13	0.10	13	7.9	683[c]		436	286	628	3.6	0.2	1,850	65
AX-40-62-801	2,200-2,366	Apr. 21, 1961	16	.13	5.8	2.2	379	3.1	432	211	205	1.8	1.2	1,040	24
AX-58-07-301	2,886-3,496[g]	Nov. 9, 1960	23	--	10	2.6	395[c]		492	304	118	2.8	.0	1,100	36
BB-32-61-701	680-780	Apr. 27, 1960	12	--	2.5	1.9	198[c]		391	75	32	--	.0	513	14
BB-40-12-101	110-130	Apr. 6, 1960	10	--	2.2	2.1	272[c]		532	122	21	4.0	3.2	698	14
BX-30-36-901	25	Feb. 5, 1946	28	.05	152	28	121	11	478	123	162	.6	26	919	494
BS-30-37-801	63	Aug. 11, 1961	23	.84	120	24	138[c]		358	126	169	.5	40	850	398
DY-31-53-706	40-128	Dec. 9, 1959	17	--	78	6.9	16	3.1	234	18	25	--	20	299	223
HB-40-35-802	478-677[g]	Sept. 9, 1955	14	.05	13	7.2	483[c]		445	309	295	3.0	4.0	1,350	62
JD-30-56-901	35- 65	Jan. 10, 1961	19	--	95	23	44	2.7	385	24	57	--	22	496	332
JP-31-61-301	96-188	Dec. 1, 1959	14	--	93	33	18	2.6	330	20	80	--	8.8	431	368
JR-38-64-601	3,354-3,692	June 13, 1944	--	--	270	42	1,420[c]		209	3,320	214	--	.2	5,370	846
LA-41-21-601	250-470	Jan. 25, 1960	14	--	104	8.6	32[c]		313	36	24	.5	44	417	296
LA-41-22-501	? -200	Mar. 19, 1946	12	3.6	63	24	147	16	411	144	74	.6	2.5	686	256
LW-40-08-801	1,955-2,083	Feb. --, 1959	--	.01	3.0	1.0	213[c]		364	75	52	.8	1.1	594	11
LY-32-26-801	55-100	Oct. 5, 1960	17	--	67	9.6	59	2.1	328	36	20	--	1.8	374	206
PX-32-36-501	440-490	Sep. 13, 1942	12	2.6	18	8.3	121[c]		342	33	18	.4	.0	382	79
PX-32-37-302	? -630	Feb. 11, 1943	9.2	.05	1.7	.7	175	4.2	414	33	12	.4	2.0	442	7
PX-32-53-302	? -510	Apr. 19, 1961	12	.02	1.5	.4	268	1.5	540	79	44	2.2	3.0	692	5
ST-40-24-803	2,253-2,492	Apr. 6, 1961	22	.08	2.8	.8	235[c]		444	81	50	.9	.0	611	10
TK-58-07-901	3,191-3,413	Jan. --, 1959	--	.94	60	17	534[c]		245	900	151	1.8	.4	1,980	220
UA-29-53-102	262	Mar. 21, 1960	13	--	74	19	20[c]		282	28	30	--	4.5	334	262
XW-29-56-301	90	Aug. 10, 1961	11	--	61	18	14[c]		262	9.2	16	0.5	12	272	226
ZK-58-29-604	2,780-3,346[g]	Mar. 1, 1960	24	0.11[d]	18	1.9	455	5.8	452	341	230	3.2	.0	1,300	53

See footnotes at end of table

Source: Texas Water Commission Bulletin 6310

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Screened Interval (feet)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bica-bonate (HCO_3) [b]	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Hard-ness as CaCO
							CARRIZO - WILCOX								
BJ-59-21-303	2,670- 2,940	May 8, 1954	25	0.5	3	2	322[c]		714	28	71	0.7	--	770	16
BJ-59-21-714	2,741-[g] 2,989	July 31, 1956	24	.03	2.4	.5	235[c]		536	.0	55	.5	0.0	581	8
BS-59-43-401	?-2,500	Nov. 11, 1959	18	--	4.5	.9	652	3.8	702	2.4	620	--	.2	1,650	14
RZ-58-40-603	475-518	Nov. 17, 1959	18	1.0	34	8.3	45	5.0	145	73	19	.1	.0	275	119
RZ-59-33-701	168-486[g]	Sep. 16, 1953	18	11	121	37	49	8.8	258	186	111	--	1.0	694	454
TK-58-32-503	120-170	Aug. 15, 1952	--	.3	15	4.0	45[c]		78	8.2	55	--	--	247	53
WK-39-51-801	190-254	Feb. --, 1943	19	.05	42	8.2	65	6.6	205	28	63	.2	1.0	334	138
WX-59-03-202	534-679[g]	Feb. --, 1943	16	.02	6.3	1.5	321	6.0	692	1.6	111	.4	2.0	807	22
WX-59-04-701	1,221-[g] 1,426	Nov. 10, 1943	25	.02	3.4	1.8	187[c]		427	3.9	48	.4	.0	480	16

See footnotes at end of table

Source: Texas Water Commission Bulletin 6310

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
BRAZOS RIVER ALLUVIUM															
AP-59-63-902	272	Apr. 13, 1964	49	0.64	16	1.9	310[c]		770	0.2	63	0.9	0.0	820	48
BB-40-14-503	Spring	Apr. 26, 1960	24	--	91	9.4	24[c]		317	22	18	0.4	11	364	266
BJ-59-20-503	70	Jan. 27, 1953	--	--	124	34	86[c]		345	99	177	--	--	865	449
		June 19, 1963	21	2.9	136	31	39[c]		592	30	24	0.4	0.5	573	467
509	67	July 17, 1963	17	4.9	108	24	269[c]		758	192	93	.5	.0	1,080	368
520	80	June 19, 1963	20	6.3	142	31	49[c]		634	30	26	.3	.0	611	482
522	--	July 17, 1963	21	1.6	142	38	72[c]		632	54	66	.3	.0	705	511
524	--	June 19, 1963	20	9.4	142	62	155[c]		708	182	126	.1	.0	1,040	610
527	70?	May 14, 1963	20	5.3	129	42	57	1.7	648	57	17	.1	.2	643	494
528	--	do	21	4.6	143	38	77	2.7	698	57	29	.2	1.2	713	514
		June 19, 1963	22	4.8	--	--	--		704	56	34	--	--	--	505
		Aug. 8, 1963	22	2.6	136	--	70[c]		684	53	28	.3	.0	686	504
529	68	June 19, 1963	21	6.7	170	32	58[c]		686	57	42	.3	.5	718	556
603	60	July 8, 1963	10	.60	18	5.6	202[c]		388	.0	134	.2	.0	561	68
		July 17, 1964	10	.62	18	5.6	197	1.5	392	.4	123	.2	.2	549	68
616	49	July 17, 1963	13	.11	8.0	3.9	516[c]		682	77	365	1.2	1.0	1,320	36
621	75	July 16, 1963	13	.04	62	18	436[c]		508	192	395	.6	1.2	1,370	228
802	62	June 27, 1963	18	2.5	147	43	134[c]		716	129	80	.2	.0	904	544
807	1,035	Nov. --, 1942	--	--	--	--	--		490	50	23	--	--	--	--
810	--	Aug. 1, 1963	21	7.4	185	34	--		694	146	49	.3	.0	864	602
902	56	June 27, 1963	18	4.0	156	31	336[c]		596	131	440	.3	.0	1,410	516
907	64	do	22	13	212	43	144[c]		766	190	137	.3	.0	1,130	706
908	68	July 16, 1964	22	8.7	182	43	61	3.4	656	155	49	.3	.2	839	631
BJ-59-21-205	2,880	June 10, 1964	22	.02	2.5	1.0	258	2.1	624	.4	53	.7	.0	647	10
714	3,060	July 31, 1956	24	0.03	2.4	0.5	235[c]		536	0.0	55	0.5	0.0	560	8
718	492	June 22, 1943	31	.73	2.0	.4	84[c]		172	20	18	.5	.0	265	6
		July 30, 1957	16	.05	.2	.1	78[c]		157	17	17	.4	.0	208	345

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
BRAZOS RIVER ALLUVIUM (Continued)															
BJ-59-21-721	70	Apr. 1, 1958	--	--	84	5	15[c]		287	19	17	--	--	407	--
728	46?	June 11, 1964	24	.60	109	14	96[c]		408	131	44	.2	5.5	625	330
901	62	May 13, 1964	49	.10	60	15	102[c]		158	36	188	.3	.2	528	211
BJ-59-38-606	68½	July 24, 1964	30	7.3	142	23	38	3.4	556	27	36	.4	.0	573	449
902	73	Aug. 15, 1957	--	--	181	34	119	--	659	44	188	--	--	1,225	--
		July 22, 1963	36	12	160	39	185[c]		870	4.8	172	.3	.0	1,030	560
909	65?	Aug. 11, 1964	40	11	154	36	74	4.1	602	28	121	.4	.0	754	532
BJ-59-39-606	61	July 9, 1963	24	2.7	152	29	95[c]		652	54	80	.4	.0	756	498
611	60	do	28	4.3	200	34	152[c]		752	90	184	.2	.0	1,060	639
701	60	do	27	.06	218	51	164[c]		764	160	225	.4	.0	1,220	754
705	73	do	27	6.2	176	37	108[c]		786	47	93	.4	.0	876	591
		July 24, 1964	27	6.4	161	36	97	3.9	736	33	85	.4	.0	806	550
907	70	July 23, 1964	24	.05	153	41	71	3.5	648	109	49	.3	.0	770	550
BJ-59-47-305	245	June 11, 1963	41	--	73	4.9	85[c]		356	25	48	.3	.0	452	202
BS-59-20-116	22½	May 14, 1964	46	0.06	46	3.7	19[c]		132	18	28	0.2	6.0	232	130
545	Spring	May --, 1964	--	--	--	--	--		380	94	135	--	--	--	444
BS-59-28-201	--	July 6, 1957	--	--	154	41	67[c]		488	58	170	--	--	978	--
202	1,600?	June 17, 1963	17	.05	2.5	.7	207	1.3	404	72	42	.3	.8	544	9
312	79	June 27, 1963	21	.15	186	51	120[c]		764	181	85	.3	.0	1,020	674
315	55	Aug. 23, 1956	--	--	44	29	381[c]		378	131	340	--	--	1,381	--
316	61	June 27, 1963	20	2.7	232	66	124[c]		788	243	155	.3	1.2	1,230	850
325	980	June 17, 1963	14	.04	1.5	.1	258	1.6	396	184	40	.4	.0	697	4
326	787	do	14	.07	1.5	.1	202	1.3	316	138	31	.2	.0	545	4
327	--	June 27, 1963	20	7.5	133	28	56[c]		636	8.8	27	0.4	0.0	587	447
501	57	July 2, 1963	19	2.2	256	68	276[c]		742	420	335	.4	.0	1,740	918

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
						BRAZOS RIVER ALLUVIUM (Continued)									
BS-59-28-503	--	Aug. 8, 1963	13	.14	1.5	.4	170[c]		236	92	60	.3	.0	454	5
610	65?	June 27, 1963	24	12	272	60	141[c]		868	174	240	.3	.0	1,340	926
BS-59-39-107	57	Aug. 5, 1964	18	.03	190	20	91	3.2	460	171	142	.1	6.5	868	556
109	56	June 27, 1963	20	7.3	142	43	139[c]		636	144	115	.2	.0	917	532
112	--	do	22	4.9	244	59	242[c]		596	332	385	.2	.0	1,580	852
410	71	June 18, 1963	22	.81	178	73	175[c]		654	276	212	.3	.0	1,260	744
426	--	Aug. 5, 1964	20	1.0	178	49	196	3.7	664	224	212	.2	1.2	1,210	646
433	59	June 27, 1963	23	15	188	39	79[c]		812	2.4	94	.4	.0	825	630
502	68	July 15, 1964	22	6.9	110	43	187	2.5	624	114	164	.5	.2	951	452
509	55?	June 18, 1963 July 6, 1964	24 26	9.3 9.0	178 179	47 46	141[c] 148	 3.9	900 890	27 28	125 143	.3 .4	.0 .0	986 1,010	638 636
703	57	June 9, 1955	--	--	288	73	292[c]		723	339	502	--	--	2,217	--
709	--	June 18, 1963	21	7.4	200	51	152[c]		768	156	175	.2	.0	1,130	709
809	76	July 13, 1964	21	5.2	132	49	124	3.0	600	55	184	.4	.2	864	531
BS-59-37-105	24	May 6, 1955	--	--	126	11	240[c]		470	49	316	--	--	1,212	--
107	30?	May 15, 1964	42	.02	135	16	211[c]		408	82	282	.4	54	1,020	403
301	57	June 18, 1963	23	9.4	338	92	276[c]		698	445	550	--	1.2	2,070	1,220
307	49	July 13, 1964	22	6.0	205	73	189	5.0	716	232	280	.4	1.8	1,360	812
601	61	June 26, 1963	24	5.0	118	38	76[c]		530	80	69	.4	.0	667	451
602	286	June 5, 1963	39	--	39	2.1	428[c]		350	359	265	.5	1.0	1,310	106
607	236?	do	38	--	40	1.5	479[c]		400	369	305	.5	4.9	1,430	106
BS-59-[illegible]8-102	58	July 13, 1964	19	9.2	208	54	187	2.8	596	283	252	.3	3.0	1,300	741
403	57	June 26, 1963	20	3.3	153	46	76[c]		576	84	124	.4	.0	787	570
404	61	do	23	5.7	208	62	197[c]		628	300	265	.4	.0	1,360	774

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3) [b]	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Hard-ness as $CaCO_3$
BRAZOS RIVER ALLUVIUM (Continued)															
BS-59-38-410	56	June 26, 1964	21	3.0	138	47	127[c]		592	128	138	0.4	0.0	891	538
802	56	Mar. 28, 1955	--	--	92	76	64[c]		378	96	170	--	--	894	
905	79	Jan. 5, 1955	--	--	110	44	46[c]		522	42	110	--	--	942	
JR-39-33-701	58	July 11, 1963	23	7.2	206	55	153[c]		636	336	142	0.3	0.0	1,230	
JR-39-41-101	45	May 10, 1961	16	--	56	51	83	1.1	536	43	16	.5	41	573	
503	42	July 29, 1963	17	.02	185	34	85	--	421	138	194	.3	29	889	
504	52	July 11, 1963	23	6.3	177	37	146[c]		728	100	149	.4	.0	991	
604	3,330	Feb. 23, 1938	--	--	182	69			504	4,380	1,620	--	0	9,580	
		June 13, 1944	--	--	193	69	2,940[c]		503	4,330	1,580	--	.8	9,620	
702	28	Aug. 4, 1964	22	1.4	255	125	306	4.7	718	253	690	.5	3.8	2,010	
704	22	May 5, 1964	27	.00	109	16	101[c]		416	114	59	.8	16	648	
903	63	Apr. 26, 1961	23	--	142	42	293	3.6	738	247	222	.3	.0	1,340	
		Aug. 4, 1964	24	6.7	181	48	312	3.7	732	303	310	.5	1.2	1,540	
JR-39-49-301	48	Apr. 26, 1961	24	--	378	83	333	5.7	570	672	600	.4	.2	2,380	
601	43	Apr. 5, 1961	22	--	55	12	60[c]		300	34	17	.3	13	361	
JR-39-50-203	51	May 6, 1964	24	.07	180	38	354[c]		420	293	510	.3	7.4	1,610	
402	41	Aug. 4, 1964	21	.11	142	39	136	3.3	648	125	104	.5	13	903	
410	61	July 29, 1954	--	--	111	35	178[c]		738	56	97	--	--	1,214	
		July 20, 1964	22	3.4	127	43	299	3.0	712	238	231	.3	1.2	1,310	
413	59	June 20, 1963	24	3.7	121	17	135[c]		596	63	79	.4	.2	733	
421	42	do	24	9.6	134	28	123[c]		664	5.2	118	.5	.0	760	
423	41	July 2, 1963	19	5.6	146	27	150[c]		650	23	173	.4	.0	859	
426	--	June 20, 1963	26	9.6	186	42	218[c]		868	12	272	.4	1.0	1,180	
502	35	July 29, 1954	--	--	79	35	42[c]		432	50	14	--	--	652	
		June 20, 1963	15	.03	82	30	63[c]		488	42	12	.6	3.6	488	
504	--	June 20, 1963	16	.10	86	28	60[c]		466	50	14	.5	4.9	489	
801	45	July 2, 1963	26	8.7	200	44	230[c]		860	126	244	.4	.0	1,290	

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							BRAZOS RIVER ALLUVIUM (Continued)								
JR-30-50-804	62	Jan. 10, 1953	--	--	149	48	177[c]		881	77	108	--	--	1,440	571
807	60	July 3, 1963	21	9.0	269	63	281[c]		630	186	588	0.4	0.0	1,720	930
813	49	June 20, 1963	24	7.3	205	39	156[c]		868	36	185	.5	.0	1,070	672
814	42	Apr. 26, 1961	19	--	320	136	380	4.4	574	473	880	.3	.2	2,500	1,360
819	30?	June 20, 1963	16	.00	177	74	205[c]		628	224	292	.4	38	1,340	746
903	32	July 3, 1963	18	.07	432	129	490[c]		412	428	1,340	.2	.8	3,040	1,610
906	56	June 20, 1963	22	2.4	375	140	366[c]		594	434	970	.3	.0	2,600	1,510
JR-39-58-204	50?	June 21, 1963	28	5.4	209	46	332[c]		1,060	120	310	.4	1.2	1,570	710
		June 20, 1964	27	4.2	165	48	304	4.3	878	129	308	.3	5.4	1,420	609
207	54	June 20, 1963	24	5.9	194	43	227[c]		812	150	235	.3	1.2	1,270	661
JR-40-48-301	45?	May 10, 1961	19	--	175	159	205	3.1	602	408	575	.4	14	1,940	1,090
801	2,900?	May 7, 1964	25	.19	5.0	1.3	288	3.0	512	154	52	2.3	.0	783	18
901	13	Mar. 3, 1961	17	--	100	8.8	31[c]		274	67	20	.2	38	417	286
JY-65-17-702	376	Apr. 15, 1964	29	0.0	48	4.0	23[c]		178	8.0	22	0.4	1.2	224	136
702	67	do	18	.48	78	66	109[c]		698	80	24	.7	15	734	466
JY-65-18-801	70	Mar. 18, 1964	19	.08	96	31	34[c]		478	24	12	.5	8.2	460	367
802	--	Mar. 19, 1964	30	.04	79	7.5	40[c]		308	4.8	41	.2	.2	354	228
JY-65-19-802	90?	July 15, 1958	--	.20	130	36	38[c]		532	17	56	--	.4	573	475
JY-65-26-201	575	Mar. 18, 1964	23	.12	60	8.4	68	1.8	258	21	17	.4	.0	380	184
304	72	Apr. 17, 1964	26	1.5	83	15	33[c]		294	8.8	63	.2	.0	374	268
505	65?	Mar. --, 1964	23	3.5	122	23	95[c]		362	47	184	.3	.0	672	399
506	140	Mar. 18, 1964	24	5.0	119	21	89[c]		344	37	182	.3	.0	641	384
602	400	July 28, 1955	27	--	106	16	95	2.2	331	32	174	--	.0	650	330
JY-65-27-202	90	July 15, 1958	--	.1	122	44	54[c]		551	53	58	--	.4	720	490
203	72?	do	--	.25	120	40	65[c]		539	53	52	--	.4	720	465

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of Well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							BRAZOS RIVER ALLUVIUM (Continued)								
JY-65-27-204	90?	July 15, 1958	--	.25	148	50	67[c]		622	49	92	--	.4	864	580
205	86	do	--	.35	134	40	49[c]		588	17	68	--	.4	720	500
206	61?	do	--	.63	156	43	72[c]		522	36	156	--	.4	876	570
304	103	do	--	.1	116	40	80[c]		527	64	65	--	.4	750	455
305	72	do	--	.05	116	40	63[c]		534	60	56	--	.4	720	455
306	100	do	--	.2	110	42	78[c]		571	47	44	--	.05	720	450
307	83	do	--	.1	112	36	50[c]		522	45	36	--	.4	546	430
308	104	do	--	.25	140	46	79[c]		536	60	106	--	.4	882	540
309	62	do	--	.25	136	37	40[c]		588	19	48	--	.4	600	495
601	86	do	--	.2	130	37	70[c]		544	55	66	--	.4	762	480
602	83?	do	--	.05	112	35	52[c]		544	40	40	--	.4	564	425
603	78?	do	--	1.0	120	42	62[c]		510	60	68	--	.4	738	475
604	78?	do	--	.3	120	42	52[c]		573	44	52	--	.4	708	475
KW-58-56-203	80	June 13, 1963	21	2.8	117	18	65	2.3	464	31	70	0.4	0.0	553	366
KW-59-48-804	900?	June 12, 1963	42	--	20	1.0	231[c]		542	.0	78	.9	.0	640	54
LW-40-14-603	Spring	May 17, 1960	21	--	93	5.2	23[c]		301	12	22	--	18	362	254
ST-40 22-201	41	July 1, 1963	11	0.03	113	4.4	31[c]		316	19	34	0.2	50	418	300
301	32	do	28	.02	300	71	236[c]		510	352	518	.3	46	1,800	1,040
ST-40-23-501	22	Apr. 24, 1958	--	--	91	12	5[c]		256	43	25	--	--	432	273
		July 1, 1963	15	.03	100	15	21[c]		328	35	26	.2	18	391	311
801	32	Jan. 31, 1955	--	--	60	52	0[c]		375	22	14	--	--	523	351
		Mar. 20, 1963	16	--	65	38	11[c]		376	17	6.0	.6	9.1	348	318
804	42	Aug. 3, 1964	19	1.6	117	25	17	1.8	414	51	26	.4	.5	462	395
ST-40-32-703	50?	May 10, 1961	19	--	113	7.2	48	1.6	318	46	67	.1	25	483	312
802	47	July 29, 1963	17	2.2	115	19	23[c]		394	48	29	.4	1.2	447	365

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of Well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
BRAZOS RIVER ALLUVIUM (Continued)															
ST-40-40-202	38	May 10, 1961	15	--	135	4.5	33	.9	358	49	36	.5	50	500	356
502	35	July 12, 1963	18	.02	138	11	48[c]		420	84	33	.7	17	557	390
505	35	do	19	.01	145	10	103[c]		424	123	96	.4	18	723	403
507	35	Apr. 24, 1958	--	--	147	16	125[c]		499	182	76	--	--	1,045	385
509	44	May 10, 1961	20	--	122	40	77	3.0	438	149	97	.4	2.5	726	469
601	28	do	18	--	142	26	116	2.6	428	151	107	.3	76	849	462
802	22	July 10, 1963	17	.00	156	6.3	67[c]		364	83	66	.4	101	676	415
TK-39-58-906	46	July 12, 1963	32	1.2	254	50	221[c]		364	448	392	0.4	0.0	1,580	839
909	47	do	23	.02	200	28	199[c]		312	218	398	.3	1.2	1,220	614
910	58	do	27	.04	180	35	204[c]		336	240	360	.5	1.2	1,210	593
TK-59-10-201	662	Oct. 25, 1952 May 12, 1964	17 17	0.01 .14	16 14	5.1 3.9	144 138[c]	0.0	276 286	0.7 1.2	103 81	0.3 .2	0.0 .0	422 396	61 51
TK-59-11-205	580	May 12, 1964	14	.04	4.0	.5	173[c]		404	.4	40	.4	.0	431	12
401	335	do	17	.16	33	5.8	47	5.0	164	49	20	.2	.0	258	106
607	268	Aug. 5, 1956	--	--	--	--	--		59	--	31	--	--	--	110
WK-39-58-201	50?	Apr. 25, 1961	24	--	185	31	148	2.2	568	119	238	0.3	0.2	1,030	589
203	47	July 25, 1963	21	1.5	119	24	60[c]		538	20	44	.5	.0	554	396
207	23	Dec. 10, 1940	--	--	--	--	--		--	30	26	--	20	--	--
305	15	Jan. 29, 1941	--	--	170	50	310[c]		921	189	250	--	20	1,422	631
307	24	Jan. 31, 1941	--	--	124	10	19[c]		250	30	57	--	93	456	351
601	46	July 17, 1963	22	.08	162	23	183[c]		327	257	226	.3	4.9	1,060	498
603	52	do	21	.40	188	51	160[c]		484	229	277	.3	1.2	1,170	679
604	49	July --, 1963	24	1.0	180	51	125[c]		544	169	217	.4	1.5	1,040	659
607	45	July 17, 1963	23	.15	167	34	188[c]		392	294	237	.4	2.8	1,140	556

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES$^{a/}$ OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3) b/	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Hard-ness as $CaCO_3$
							BRAZOS RIVER ALLUVIUM (Continued)								
WK-39-58-902	48	July 25, 1963	19	.05	220	82	219c/		580	526	240	.3	.0	1,590	886
903	55	July 21, 1963	21	.04	140	33	147	1.9	563	184	111	.3	2.0	916	485
WK-39-59-702	65	July 3, 1963	26	4.9	125	25	59c/		456	38	92	.3	.0	589	415
703	70	Aug. 4, 1964	19	.02	123	18	69	2.0	368	72	103	.3	11	598	381
WK-59-02-305	74	do	37	1.4	279	19	77	3.4	416	334	175	.2	7.2	1,140	774
306	--	do	28	13	162	43	184	2.5	846	162	87	.4	.2	1,090	581
601	60	July 12, 1963	20	3.2	184	49	255c/		816	274	180	.3	.5	1,360	656
WK-39-03-101	67	July 25, 1963	26	8.8	138	35	167c/		854	66	58	.3	.0	911	488
105	--	July 12, 1963	21	.75	135	38	166c/		816	82	69	.4	1.8	915	494
202	683	Feb. --, 1943	16	.02	6.3	1.5	321	6.0	692	1.6	111	.4	2.0	807	22
402	63	July 18, 1963	17	.01	104	8.9	37c/		324	33	35	.2	32	426	296
WK-59-03-409	64	July 18, 1963	22	4.6	162	43	82c/		728	74	52	0.3	13	807	581
413	58	Aug. 14, 1964	21	.03	147	27	145	2.4	468	124	195	.3	.0	892	478
502	46	May 26, 1961 Aug. 4, 1964	21 21	-- .03	115 117	17 17	162 151	2.2 2.1	452 446	144 123	134 141	.1 .2	9.3 1.8	827 793	357 362
503	63	May 26, 1961	19	--	121	41	107	3.2	514	119	113	.2	1.0	778	470
504	55	July 9, 1964	21	.03	116	21	70	2.3	442	57	80	.2	3.0	588	376
507	67	July 18, 1963	22	.02	94	8.1	87c/		338	35	101	.2	1.5	515	268
701	51	Apr. 26, 1961	18	--	115	24	51	2.8	520	43	22	.3	1.0	533	386
702	58	do	--	--	--	--	--		628	--	31	--	--	--	420
703	59	do	20	--	120	33	145	1.9	686	128	49	.3	.0	834	435
801	65	do	19	--	110	35	117	3.3	552	101	82	.2	.0	739	418
810	51?	Aug. 4, 1964	20	3.5	272	88	261	3.4	684	324	505	.3	1.8	1,810	1,040
905	70	May 25, 1961 June 21, 1963	16 16	-- 3.7	154 154	33 31	71 72c/	6.1	276 274	317 307	89 86	.4 .6	.0 .0	823 802	520 512
906	56	Aug. 11, 1959	--	--	440	133	394c/		704	6.56	882	--	--	964	--

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							BRAZOS RIVER ALLUVIUM (Continued)								
WK-59-03-913	55	Apr. 27, 1961	21	--	170	84	124	2.1	556	123	315	.5	.2	1,100	770
914	50?	May 25, 1961	23	--	440	129	373	7.9	718	570	890	--	1.8	2,790	1,630
915	--	May 26, 1961	22	--	418	139	326	7.1	610	612	820	.2	1.8	2,650	1,610
917	69	June 21, 1963	20	5.8	283	74	242[c]		726	458	328	.3	1.2	1,760	1,010
919	--	July 31, 1963	18	4.2	124	18	53[c]		308	136	74	.4	.0	584	384
WK-59-04-701	1,440	Nov. 10, 1943	25	.02	3.4	1.8	187[c]		395	3.9	48	.4	.0	480	16
702	1,275	Feb. --, 1943	6.2	.12	4.8	.8	175	7.6	376	2.9	46	.2	2.0	448	16
WK-59-11-203	69	July 26, 1963	20	5.9	160	40	161[c]		812	93	106	.3	.0	980	564
204	1,250	July 26, 1954	--	--	6	18	106[c]		275	9	32	--	--	469	90
304	69	July 3, 1963	19	5.0	146	34	111[c]		666	66	92	.2	.0	796	504
305	67	Sep. --, 1955	--	--	155	45	56[c]		462	104	106	--	--	958	572
306	66	July 3, 1963	22	5.9	150	42	100[c]		604	128	96	0.2	0.0	836	546
310	49	do	24	7.0	131	35	118[c]		774	21	50	.4	.0	761	471
311	276	May 10, 1955	--	--	12	13	424[c]		824	33	160	--	--	1,508	--
315	55	Sep. 14, 1956	--	--	140	49	262[c]		756	182	220	--	--	1,609	--
316	50	do	--	--	101	34	203[c]		470	151	184	--	--	1,161	--
322	269	Aug. 7, 1964	14	--	9.5	3.0	191	2.0	458	16	41	1.0	.0	503	36
324	--	June 21, 1963	21	6.8	127	27	152[c]		792	28	57	.4	.0	802	428
325	--	do	20	4.3	119	24	98[c]		594	48	49	.7	.0	651	396
326	--	July 3, 1963	24	7.3	154	35	148[c]		812	39	99	.3	4.8	904	528
327	68	do	20	11	232	68	180[c]		664	328	258	.3	.0	1,410	858
605	62	June 19, 1963	19	.66	125	41	76[c]		632	72	36	.4	.2	681	480
612	60?	June 19, 1963	21	2.0	110	40	51[c]		592	40	16	.5	.0	570	439
	280?	Aug. 12, 1964	21	.81	118	39	57	3.0	624	45	20	.4	.0	611	455
		do	--	--	--	--	--	--	568	--	19	--	--	--	408

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Cal- cium (Ca)	Magne- sium (Mg)	Sodium (Na)	Potas- sium (K)	Bicar- bonate (HCO_3) [b]	Sul- fate (SO_4)	Chlo- ride (Cl)	Fluo- ride (F)	Ni- trate (NO_3)	Dis- solved solids	Hardness as $CaCO_3$
							BRAZOS RIVER ALLUVIUM (Continued)								
WK-59-11-615	61	June 19, 1963	15	.04	120	24	115[c]		292	134	190	.4	1.2	744	398
616	--	Aug. 12, 1964	16	.04	92	27	55	1.8	408	68	40	.5	.2	502	340
WK-59-12-102	61	May 26, 1961	20	--	305	80	240	3.8	604	398	490	.1	2.0	1,840	1,090
		June 19, 1963	22	8.2	294	75	212[c]		764	367	350	.2	1.0	1,700	1,040
		July 17, 1964	23	4.1	212	54	176	4.9	828	147	218	.3	2.5	1,250	751
110	--	June 18, 1963	20	3.3	136	67	98[c]		604	94	166	.4	.2	879	615
	--	Aug. 8, 1963	--	--	--	--	--		578	--	162	--	--	--	602
111	--	June 19, 1963	21	3.6	218	73	141[c]		548	217	335	.3	1.2	1,280	844
202	57	Aug. 6, 1964	22	3.9	153	15	88	3.3	362	166	123	.2	1.8	749	443
410	62	Mar. 16, 1950	--	--	194	37	8[c]		738	3	32	--	--	1,012	637
411	52	June 18, 1963	20	4.6	196	67	168[c]		640	203	278	0.2	1.5	1,250	764
417	58	June 28, 1963	22	1.2	124	32	47[c]		596	13	28	.3	.5	560	441
423	--	June 19, 1963	22	7.0	140	27	65[c]		640	19	40	.5	.2	649	460
	--	Aug. 8, 1963	--	--	--	--	--		646	--	38	--	--	--	480
427	57	June 18, 1963	18	5.8	164	51	239[c]		662	162	302	0.3	1.0	1,260	619
434	--	do	20	6.9	189	58	149[c]		628	170	242	.2	1.2	1,140	710
435	--	do	18	2.7	108	46	81[c]		546	66	83	.3	.2	671	458
436	--	June 19, 1963	24	5.9	150	40	80[c]		760	21	46	.5	1.2	737	538
437	--	do	27	5.9	140	39	85[c]		736	31	42	.4	.2	727	510
438	--	June 18, 1963	19	3.6	102	33	73[c]		506	44	60	.3	3.0	584	390
440	320	Aug. 24, 1964	11	.98	14	3.2	133	3.9	312	58	24	.2	.0	400	48
701	--	Aug. 12, 1964	12	2.3	40	6.9	35	5.5	180	38	14	.2	.0	241	128
	300?	do	--	--	--	--		--	180	--	18	--	--	--	120
702	68	June 19, 1963	22	6.5	160	34	85[c]		724	44	58	.5	.00	760	539
703	69	do	20	4.7	166	35	88[c]		704	49	85	.3	.0	790	558
705	62	July 3, 1963	18	4.8	152	42	116[c]		732	61	99	.2	.0	849	552
709	65	June 19, 1963	25	8.0	153	31	85[c]		696	37	59	.3	.0	734	509

See footnotes at end of table

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO$_2$)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO$_3$) [b]	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Dissolved solids	Hardness as CaCO$_3$
BRAZOS RIVER ALLUVIUM (Continued)															
WK-59-12-721	73	July 3, 1963	20	2.5	146	43	133[c]		620	122	138	.2	.0	908	542
722	--	July 3, 1963	24	9.8	200	49	180[c]		892	137	154	.2	.0	1,180	700
804	70	July 19, 1963	19	4.8	127	64	204[c]		602	130	278	.4	1.1	1,120	580
815	45	Feb. 16, 1954	--	--	160	35	28[c]		494	11	113	--	--	859	546
828	--	July 8, 1963	17	3.9	128	28	137[c]		582	74	126	.3	.0	797	434
WK-59-20-101	65	July 27, 1964	25	4.0	115	20	99	6.9	254	143	164	.3	.0	698	370
105	69	July 19, 1963	22	8.4	156	34	84[c]		684	42	75	.4	.0	750	529
109	58	July 17, 1964	25	5.4	152	29	141	3.4	780	65	80	.3	.2	880	498
110	75	July 18, 1963	22	4.9	135	25	98[c]		708	27	32	.2	.0	688	440
201	55	June 19, 1963 Aug. 8, 1963	14 --	2.1 --	61 --	5.3 --	195[c] --		624 626	6.4 --	56 51	.6 --	.0 --	646 --	174 194
212	55	Aug. 6, 1964	15	1.5	69	21	262	2.2	648	117	138	.4	.2	944	258
214	75	Apr. 27, 1961	23	--	132	25	85	3.2	580	49	72	.2	.0	675	432
216	--	June 19, 1963 Aug. 8, 1963	17 --	5.6 --	228 --	82 --	219[c] --		596 586	269 --	435 440	0.3 --	0.2 --	1,540 --	906 890
311	--	Aug. 1, 1963	15	5.0	244	71	347[c]		376	456	618	.3	.0	1,940	901
526	73	June 28, 1963	19	5.5	163	53	137[c]		746	136	118	.3	2.0	996	624
WK-59-55-904	300	June 14, 1963	23	--	76	13	54	7.4	372	18	30	0.4	0.2	400	243
WK-59-56-103	865	June 13, 1963	46	--	17	1.3	209		508	.2	60	.8	.0	584	48
WK-59-64-201	728	June 23, 1960	21	0.37	29	6.3	119	3.4	356	3.2	48	.6	.0	406	100
WK-66-08-102	67?	Apr. 18, 1964	19	.17	92	16	34[c]		342	34	36	.2	2.0	401	296
103	337	Apr. 8, 1964	18	.08	54	16	134[c]		394	35	93	.3	.2	544	200
202	75?	do	24	.72	65	6.8	24	1.4	230	18	28	.2	.2	281	190
WK-66-16-104	64	Apr. 9, 1964	21	--	134	30	52[c]		602	32	31	.3	.2	596	458
201	120	do	42	.01	83	13	44	1.5	318	7.8	59	.3	.8	407	260

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							BRAZOS RIVER ALLUVIUM (Continued)								
YY-59-46-401	140	July 30, 1964	47	0.06	64	3.0	67	9.3	350	21	18	0.3	0.2	402	172
502	701	do	50	.03	11	.1	225[c]		352	59	117	.8	.2	636	28
YY-59-55-703	70	Aug. 15, 1963	28	.01	104	5.1	29[c]		352	5.2	33	.6	.2	378	280
806	1,074	July 13, 1942	13	.07	10	1.3	139[c]		306	.7	55	1.6	.0	377	30
YY-59-56-106	71?	Aug. 21, 1964	24	3.1	119	17	62	2.0	463	54	54	.2	.0	560	367
YY-59-63-502	50?	Apr. 10, 1964	15	.16	102	38	103[c]		365	57	201	.4	.0	691	411

See footnotes at end of table

Source: Texas Water Development Board - Report 41

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3) [b]	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Hard-ness as $CaCO_3$
							GULF COAST								
AP-59-60-702	112	Dec. 2, 1965	27	0.08	155	2.8	33.0	1.1	350	15	60	0.4	96	562	398
AP-59-61-402	186	Nov. 30, 1965	54	4.9	76	4.5	73[c]	--	364	15	37	.3	.2	439	208
501	180	do	30	5.1	96	8.9	51[c]	--	340	21	60	.4	.2	434	276
701	98	Mar. 10, 1937	--	--	--	--	--	--	293	40	54	--	110	526	--
803	725	1963 Nov. 23, 1965	-- 49	-- .52	44 55	10 5.1	92 94	16 12	342 368	19 12	71 43	-- .3	-- 0	463 451	-- 158
AP-59-62-501	132	Jan 12, 1937	--	--	--	--	--	--	287	40	36	--	[h]	348	--
702	313	Nov. 11, 1965	27	.25	94	9.6	38	3.9	350	12	46	.3	0	403	274
AP-59-63-701	140	Apr. 21, 1966	27	.23	96	8.9	48	2.7	346	11.0	64	.3	.2	428	276
901	75	May 14, 1965	30	0	65	4.9	31	1.2	240	11	32	.3	.2	294	182
902	1,228	Jan. 7, 1937 Apr. 13, 1964	-- 49	-- .64	36 16	-- 1.9	280[c] 310[c]	-- --	695 770	32 .2	68 63	-- .9	[h] 0	758 820	90 48
905	565	Jan. 6, 1937	--	--	--	--	--	--	323	51	60	--	[h]	432	--
AP-66-05-102	91	Apr. 21, 1966	21	1.4	120	3.9	24	1.4	374	18	30	.4	9.6	412	316
702	120	Dec. 10, 1965	24	2.7	100	9.4	49	1.8	354	14	66	.6	0	440	288
801	160	Dec. 14, 1965 Apr. 22, 1966	-- 20	-- 2.5	-- 137	-- 15	-- 92	-- 5.9	292 300	22 21	250 245	-- .5	-- .8	-- 685	410 404
901	80	Dec. 14, 1965 Apr. 22, 1966	-- 25	-- .10	-- 126	-- 15	-- 180	-- 2.9	-- 378	-- 84	275 265	-- .6	-- 2.0	-- 886	-- 376
AP-66-06-102	110	Dec. 16, 1965	--	--	--	--	--	--	--	--	--	--	--	--	--
104	121	Apr. 21, 1966	28	.05	102	5.7	38	1.9	400	6.4	21	.4	.2	401	278
601	786	Feb. 19, 1944	29	.08	68	12	92	9.1	367	46	58	.2	.2	495	219
603	900	Jan. 5, 1966	29	.13	46	11	100	5.2	311	50	52	.2	.2	447	161
AP-66-07-501	28	Feb. 18, 1937	--	--	--	--	--	--	12	10	34	--	72	173	--
AP-66-08-105	210	Jan. 13, 1966	20	6.8	108	26	107	5.7	390	26	195	.2	.2	680	376
AP-66-14-202	113	Apr. 22, 1966	26	.07	18	2.3	20	1.1	72	5.0	22	.3	4.8	135	54

See footnotes at end of table

Source: Texas Water Development Board - Report 68

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							GULF COAST								
AP-66-14-801	74	Dec. 17, 1965	24	1.2	14	1.2	25	.9	41	5.6	39	.1	.2	130	40
AP-66-15-101	164	Apr. 21, 1966	27	.04	52	2.2	24	.9	181	6.4	27	.2	.8	230	139
902	304	Feb. 19, 1944	22	.02	48	2.8	17	2.9	155	3.4	29	.2	1.2	203	131
AP-66-16-405	102	Feb. 17, 1966	25	--	71	4.1	19	1.0	212	9.6	22	.2	25	281	194
AP-66-22-301	752	July 29, 1955 June 16, 1965	32 --	-- --	41 --	3.2 --	26 --	1.6 --	148 152	7.6 7.8	34 32	-- --	1.0 --	246 --	115 121
AP-66-23-102	598	do	28	0	41	3.3	23	1.3	148	6.6	29	.2	.5	206	116
201	941	May 13, 1965	27	.01	30	3.2	53	1.5	161	10	47	.3	0	251	88
202	1,326	do	23	0	26	2.9	125	1.3	206	27	112	.8	.8	420	77
205	116	Feb. 18, 1966	32	--	51	5.1	46	.9	184	6.8	66	.2	1.5	300	148
301	120	do	27	--	70	4.3	57	.7	216	9.2	88	.2	7.7	370	192
402	890	May 14, 1965	28	0	54	5.2	50	1.6	193	12	69	.2	0	315	156
602	120	Feb. 18, 1966	33	--	72	6.9	53	.5	208	8.8	103	.2	2.2	382	208
902	556	June 16, 1965	33	.0	58	4.9	38	.9	176	8.6	68	.2	1.0	300	165
AP-66-24-801	610	Feb. 15, 1960 Jan. 20, 1966	27 27	.07 .02	48 50	3.2 3.2	19 17	1.5 1.4	151 149	6.0 6.6	33 32	.1 .2	.8 .5	213 214	133 138
802	96	Feb. 18, 1966	23	--	74	12	54	1.5	324	12	58	.4	.2	394	234
YW-59-55-603	106	Jan. 31, 1966	28	0.05	108	13	57	--	232	14	168	0.3	7.7	510	324
604	178	do	--	.17	--	--	--	--	360	17	36	--	--	--	137
904	350?	June 14, 1963	23	--	76	13	52	4.7	372	18	30	.4	.2	400	243
YW-59-56-103	850?	June 13, 1963	46	--	11	1.3	209[c]	--	508	0.2	60	0.8	0.0	584	48
204	147	Jan. 28, 1966	21	0.01	46	11	45	3.4	264	18	22	.5	.2	297	162
501	379	June 11, 1949 Feb. 1, 1966	34 20	-- --	78 80	21 18	71[c] 65[c]	-- --	336 318	15 15	102 98	-- .3	.2 .2	480 452	281 274
YW-59-64-202	745	Apr. 5, 1944	19	.06	30	6.1	124[c]	--	370	6.0	39	.08	.2	408	100
203	868	Jan. 2, 1930 Jan. 6, 1930	29 --	-- --	40 50	11 7.5	138[c] 115[c]	-- --	390 372	6.7 10	85 66	-- --	-- --	517 451	145 156
901	900?	June 14, 1965	26	.02	28	5.4	23	1.5	129	7.2	21	.3	2.0	177	92

See footnotes at end of table

Source: Texas Water Development Board - Report - Report 68

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a/] OF GROUNDWATER - PRIMARY ACUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium (Na)	Potas-sium (K)	Bicar-bonate (HCO_3) b/	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Hard-ness as $CaCO_3$
GULF COAST (Continued)															
YW-60-49-201	218	June 11, 1949	29	--	45	8.6	18c/	--	192	4.3	17	--	.2	220	148
502	66	do	32	--	9.8	.7	36c/	--	40	8.0	43	--	3.8	154	27
701	212	Apr. 21, 1966	24	4.0	26.0	3.6	33.0	2.2	86	4.6	42	.1	.2	167	80
901	111	June 11, 1949	32	--	8.4	1.2	30c/	--	58	3.9	27	--	2.2	128	26
YW-59-50-701	75	do	42	--	23	5.4	38c/	--	73	4.1	70	--	.5	242	79
703	94	Feb. 3, 1966	43	.03	12	3.9	57	1.0	63	12	76	.3	.2	236	46
YW-60-57-101	570	Jan. 28, 1966	20	.02	35	10	98	3.7	358	20	28	.4	.0	391	130
103	576	1930 Oct. 1942	10 28	-- 3.8	34 14	11 2.6	70c/ 29c/	-- --	255 71	23 2	36 34	-- .2	-- 0	309 169	130 46
104	571	Mar. 24, 1928	33	--	36	5.5	111c/	--	336	30	34	--	--	113	--
506	558	Jan. 26, 1966	21	.53	31	8.2	60	2.5	240	15	22	.5	.2	279	111
YW-60-58-105	715	June 29, 1965	25	--	48	4.0	32	--	176	6.8	38	.3	.2	241	136
107	40	June 11, 1949	21	--	92	37	220	--	108	95	210	--	465	1,190	382
203	300	do	44	--	35	4.5	36	--	131	5.4	50	--	.5	247	106
YW-65-01-202	85	Feb. 22, 1966	15	.21	11	3.8	37	.8	64	.4	44	.2	8.3	152	43
403	824	May 20, 1965	21	0	42	7.1	83	2.1	238	7.4	84	.3	.0	364	134
501	842	Sep. 8, 1965	25	0	50	8.6	29	1.6	172	9.2	55	0.2	0.8	264	160
502	828	Aug. 11, 1947	--	--	--	--	--	--	202	3	50	--	--	128	--
503	845	June 7, 1949	14	--	42	6.6	34c/	--	169	19	33	--	.2	232	132
602	959	July 2, 1965	22	--	48	15	65	3.9	320	17	35	.5	.2	364	182
803	1,330	Aug. 12, 1965	23	.03	48	6.8	75	2.4	212	38	74	.4	.2	372	148
902	1,332	May 12, 1965	26	.01	52	4.0	91	1.3	182	24	120	.5	.2	408	146
903	884	Aug. 11, 1947	--	--	--	--	--	--	206	3	44	--	--	--	128
YW-65-02-701	392	June 11, 1965 Aug. 12, 1965	30 30	.0 --	71 72	4.6 4.5	20 21c/	1.0 --	226 226	.8 .8	40 41	.2 .2	.0 .5	279 281	196 198
707	554	Aug. 11, 1947	--	--	--	--	--	--	194	2	36	--	.5	--	135

See footnotes at end of table

Source: Texas Water Development Board - Report 68

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
GULF COAST (Continued)															
YW-65-09-102	936	Aug. 12, 1947	--	--	--	--	--	--	194	9	64	--	--	132	--
		June 11, 1965	25	.04	47	6.5	34	1.1	180	5.6	41	.2	5.0	254	144
203	1,020	May 24, 1965	23	0	54	8.1	65	2.0	228	17	78	.3	.2	360	168
204	839	June 11, 1965	23	.02	50	9.5	44	2.2	200	15	59	.3	.2	301	164
306	920	June 7, 1949	33	--	43	4.9	51[c]	--	217	5.9	38	--	1.2	280	127
307	767	--	--	--	--	--	--	--	204	2	48	--	--	--	148
308	641	Aug. 11, 1947	--	--	--	--	--	--	202	3	50	--	--	--	176
309	800?	do	--	--	--	--	--	--	186	2	54	--	.8	--	189
402	100	Nov. 5, 1948	23	--	77	6.2	13[c]	--	228	6.6	28	--	15	298	218
502	530	May 27, 1965	26	.02	49	6.3	36	1.2	176	4.8	53	.2	2.5	266	148
504	760	Aug. 12, 1947	--	--	--	--	--	--	192	2	80	--	1.0	--	128
505	600	June 7, 1949	28	--	54	3.9	45	--	180	5.3	67	--	1.2	292	151
506	586	do	26	--	60	9.6	41	--	214	11	64	--	.2	325	189
507	--	Aug. 14, 1947	--	--	--	--	--	--	208	5	80	--	.5	--	155
601	697	May 20, 1965	27	.00	60	7.4	40	1.3	200	8.6	67	.2	.2	376	180
		Aug. 12, 1965	26	--	58	6.7	45[c]	--	204	11	64	.3	.2	311	172
604	478	June 7, 1949	28	--	48	7.1	38[c]	--	178	12	52	--	.2	271	149
		May 17, 1965	30	--	50	5.2	30[c]	--	168	.2	51	.1	.5	250	146
605	653	Aug. 14, 1947	--	--	--	--	--	--	190	3	54	--	--	--	135
802	540	June 22, 1960	22	.19	61	8.1	40	2.2	190	19	73	.4	.00	334	186
805	860	Aug. 30, 1965	27	.02	78	9.1	40	1.3	232	8.6	81	.2	.2	359	232
YW-65-09-902	530	May 17, 1965	30	0	65	5.8	31	1.0	216	3.4	56	0.2	0.0	298	186
		July 21, 1965	29	--	65	5.3	32[c]	--	216	2.4	52	.2	0	292	184
		do	--	--	--	--	--	--	216	2.0	53	--	--	--	180
904	256	Aug. 11, 1947	--	--	--	--	--	--	202	2	50	--	--	--	155
YW-65-10-101	982	June 15, 1965	23	.00	45	5.3	46	1.5	217	8.2	38	.3	.2	275	134
102	585	May 24, 1965	29	.00	62	5.7	28	.9	210	3.2	46	.2	.8	279	178

See footnotes at end of table

Source: Texas Water Development Board - Report 68

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							GULF COAST (Continued)								
YW-65-10-107	470	Aug. 11, 1947	--	--	--	--	--	--	202	3	46	--	--	--	142
402	400?	do	--	--	--	--	--	--	200	2	52	--	.8	--	135
403	246	June 7, 1949	32	--	64	7.9	35[c]	--	231	3.3	52	--	1.2	308	192
YW-66-08-103	337	June 7, 1949	18	.08	54	16	134[c]	--	394	35	93	.3	.2	544	200
201	583	June 14, 1965	23	.17	46	12	74	2.8	256	14	72	.4	.0	370	164
602	1,608	July 30, 1952	32	--	19	2.4	235[c]	--	431	90	84	.8	.5	719	58
		June 11, 1965	33	--	9.8	2.3	300[c]	--	504	145	84	1.1	.0	824	34
902	176	May 28, 1965	26	0.21	22	4.9	33	1.0	76	5.8	55	0.2	4.2	189	76
905	1,602	June 7, 1949	22	--	37	14	145[c]	--	269	118	86	--	.2	557	150
YW-66-16-104	64	Apr. 9, 1964	21	--	134	30	52[c]	--	602	32	31	.3	.2	596	458
105	210	Mar. 18, 1964	21	--	48	4.0	25[c]	--	176	8.4	26	.2	1.0	221	136
201	120	Apr. 9, 1964	42	.01	83	13	44	1.5	318	7.8	59	.3	.8	407	260
303	85	Feb. 24, 1966	24	--	106	8.6	67	1.1	390	1.0	80	.3	1.8	491	300

Location of Well	Screened interval (ft.)	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Manganese (Mn)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
Fort Bend County, 30 mi. W Houston	7-172	--	--	100	--	10	28	290	4	78	--	.5	407	290
Fort Bend County, 20 mi. SW Houston	555-[g] 802	--	--	68	--	12	35	238	10	63	--	--	305	219
	1,545-1,606	14	.03[d]	14	--	3.6	119 6.6	259	16	61	1.0	.2	363	50
Brazoria County, 14 mi. S Houston	?-87	--	--	80	--	28	96	427	--	110	--	--	544	318
Brazoria County, 25 mi. S Houston	590-715	18	.04	16	--	5.0	259	342	1	240	1.0	.0	709	60

See footnotes at end of table

Source: Texas Water Commission Bulletin 6305

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a/] OF GROUNDWATER - PRIMARY AQUIFERS

Location of Well	Screened interval (ft.)	Silica (SiO_2)	Iron (Fe) (total)	Cal-cium (Ca)	Mange-nese (Mn)	Magne-sium (Mg)	Sodium and potassium (Na + K)	Bicar-bonate (HCO_3) b/	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Hard-ness as $CaCO_3$
GULF COAST (Continued)														
3 mi. SE Angleton, Brazoria County	?-235	17	.05[d/]	14	--	5.2	284	428	2	224	1.3	.8	759	56
11 mi. NW Texas City, Galveston County	498-[g/] 576	14	.02[d/]	5.4	--	1.3	184 3.6	370	2	79	1.0	.2	471	19
4 mi. W Texas City, Galveston County	578-[g/] 700	15	.50	7.7	--	2.2	265 3.4	430	2	178	1.0	1.2	698	28
In Texas City, Galveston County	897-1,004	--	--	39	--	15	797	350	2	1,100	--	1.2	2,130	159
10 mi. W Texas City, Galveston County	703-[g/] 884	28	--	--	50	19	561	332	0.8	815	--	0.2	1.640	203
12 mi. NW Texas City, Galveston County	647-[g/] 767	26	--	--	19	5.6	236	347	2.0	210	0.6	.0	680	70
In Galveston, Galveston County	?-397	17	--	--	18	14	562	745	1.8	490	--	7.8	1 480	102
do	1,185-[g/] 1,310	35	--	--	87	53	2,130	330	.0	3,400	--	--	5 870	435
11 mi. SW El Campo, Wharton County	134-[g/] 599	18	--	105	--	20	61 2.2	291	24	158	--	1.0	532	344
13 mi. NW El Campo, Wharton County	110-[g/] 388	39	--	105	--	7.2	54 1.0	274	16	121	--	.5	479	292
11 mi. W Wharton, Wharton County	77-[g/] 186	24	--	60	--	6.7	23 1.7	220	6.0	28	.2	3.2	264	177
Wharton, Wharton County	212-[g/] 393	--	.15	67	--	14	32	256	16	47	--	.8	303	225
13 mi. SE Wharton, Wharton County	246-[g/] 791	24	--	63	--	17	42 2.5	292	16	49	--	.0	359	227
8 mi. SE Wharton, Wharton County	140-532	28	--	74	--	15	39 2.6	255	14	79	.4	.5	411	246
15 mi. Wharton, Wharton County	40-405	33	--	96	--	7.6	59 1.2	279	16	115	--	1.0	499	270

See footnotes at end of table

Source: Texas Water Commission Bulletin 6305

TABLE AI-1 (Continued)

CHEMICAL ANALYSES[a] OF GROUNDWATER - PRIMARY AQUIFERS

Location of Well	Screened interval (ft.)	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Manganese (Mn)	Magnesium (Mg)	Sodium and potassium (Na + K)		Bicarbonate (HCO_3) b/	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
GULF COAST (Continued)															
12 mi. W Rosenberg, Fort Bend County	?-245	20	--	67	--	20	99		475	14	41	.8	.0	496	249
Rosenberg, Fort Bend County	970-1,590	15	.13	22	.00	6.1	87	2.1	253	.2	43	.4	.0	300	80
14 mi. S Rosenberg, Fort Bend County	234-1,090	19	--	74	--	18	185	2.6	278	14	305	--	2.5	792	258
In Brazoria County, 22 mi. SE Rosenberg, Fort Bend County	192-837	18	--	36	--	8.1	128		324	2.8	93	.5	.0	445	124
In Brazoria County, 19 mi NE Bay City, Matagorda County	?-875	15	--	26	--	9.5	428		382	2.4	508	1.1	.0	1,180	104
12 mi. NW Freeport, Brazoria County	439-468	14	.96	22	.2	12	357	2.9	382	.4	408	.8	.0	1 010	104
Freeport, Brazoria County	206-247	16	--	0.4	23	15	302	--	572	2	203	--	--	1 145	--
4 mi. NE Bay City, Matagorda County	?-530	24	--	--	83	27	119	2.3	456	16	134	--	0.0	630	318
16 mi. SE Bay City, Matagorda County	193-728	22	--	--	126	35	151		460	44	256	0.3	1.8	935	458
14 mi. S Bay City, Matagorda County	150-720	21	--	--	37	8.8	143	--	366	11	90	--	.2	498	128
13 mi. W Bay City, Matagorda County	520-761	28	--	--	61	19	52	2.7	291	17	68	--	.0	391	230
19 mi. SW Bay City, Matagorda County	85-466	28	--	--	62	30	143	1.9	422	46	140	.6	.0	671	278
5 mi. NW Palacios, Matagorda County	?-696	21	--	--	26	16	93	2.3	286	18	60	.5	.0	378	131
4 mi. E Palacios, Matagorda County	?-770	17	--	--	9.9	4.3	177		344	11	94	--	.0	488	42

Source: Texas Water Commission Bulletin 6305

a/ mg/l except where otherwise specified
b/ Includes the equivalent of any carbon present
c/ Sodium and potassium calculated as sodium
d/ Iron in solution
e/ Well used for public supply
f/ Well on river terrace or flood plain
g/ Not screened throughout interval
h/ rate han 2

TABLE A I-2

CHEMICAL ANALYSES[a] OF GROUNDWATER - SECONDARY AQUIFERS

Well	Depth of well (ft.)	Date of Collection	Silica (SiO_2)	Iron (Fe) (total)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3) [b]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
							EDWARDS - TRINITY								
BA-28-03-602	57	June 29, 1961	52	--	118	52	180[c]		270	240	270	3.5	47	1,100	508
RU-24-05-401	60	Apr. 18, 1952	12	--	180	204	455[c]		344	1,070	620	2.0	.5	2,710	1,290
							SANTA ROSE								
JU-29-19-901	90	Nov. 24, 1942	--	--	84	60	22[c]		396	199	135	--	0.2	795	456
JU-29-20-501	62	Oct. 7, 1943	--	--	80	77	51[c]		393	193	69	--	8.4	722	516
UA-29-36-601	165	Mar. 22, 1960	21	.00[d]	94	27	31	6.0	258	74	75	1.6	20	511	346
UA-29-36-905	180	Apr. 13, 1960	15	--	79	12	16	2.0	275	22	19	--	4.0	307	246
WZ-29-01-601	147	July 23, 1960	26	--	74	32	33[c]		351	67	21	.3	.0	426	316
WZ-29-09-201	285	do	12	--	9.5	4.5	49[c]		318	44	40	.7	.5	416	42
WZ-29-10-401	190	do	26	--	62	19	40[c]		282	47	24	1.0	2.2	360	232
WZ-29-10-503	320	May 4, 1961	14	--	30	10	122	2.5	326	68	32	1.7	.0	440	116
WZ-29-19-101	Spring	Dec. 20, 1943	--	--	63	21	16[c]		253	29	25	--	6.9	286	244
WZ-29-19-202	41	Dec. 2, 1943	--	--	69	17	31[c]		275	29	32	--	12	326	242
							QUEEN CITY								
BJ-59-21-301		May --, 1938	--	--	4.8	2.1	485[c]		1,070	6.9	72	1.6	.1	1,150	21
							SPARTA								
BJ-59-21-302		Nov. 10, 1942	18	.04	2.0	.3	67[c]		156	5.7	12	.2	.0	184	6
BJ-59-21-718		June 22, 1943	31	.73	2.0	.4	84[c]		172	20	18	.5	.0	265	6
							EDWARDS								
ZK-58-19-802		Feb. 10, 1941	10	0.05	124	23	12[c]		360	36	35	.0	60	484	404
ZK-58-27-801		Mar. 30, 1941	--	.02	109	23	6.7[c]		374	40	15	.2	14	408	367
							WOODBINE								
LW-32-55-905		May 19, 1960	12	--	32	16	308[c]		307	466	56	--	0.2	1,040	146
LW-32-63-901		Jan. --, 1943	10	0.02[c]	2.7	1.1	278	11	508	160	35	0.2	2.5	762	12

Source: Texas Water Commission Bulletin 6310

[a] mg/l except where specified
[b] Includes the equivalent of any carbon present
[c] Sodium and potassium calculated as Sodium
[d] Iron in solution

APPENDIX II

BRAZOS RIVER BASIN SIMULATION MODEL

General

A mathematical model was constructed to simulate hydrologic conditions expected in the year 2020. The model was used to predict surface water quality with salinity control projects in place. Numerous optional projects were tested, however, the following discussion will be restricted primarily to a description of the Corps of Engineer Plan 4A since this plan appears to produce the most desirable result. Alternative Plan 4B discussed in Appendix III is the same as Plan 4A with the reservoir at Dam Site 20 deleted.

Model Design

Figure AII-1 is a schematic drawing of the five segments of the model. Separation into segments was necessary to adjust to the computer limitations. Each segment can be operated separately or all segments can be linked to run sequentially. When the segments are linked, overlapping or duplicate parts are eliminated. The schematic drawing shows all possible elements for all optional plans examined. Individual elements may be "zeroed out" when a specific plan is examined.

The model was first designed to duplicate, as closely as possible, flow and quality conditions observed during the period water years (WY) 1941-62. The model was then modified to include water supply reservoirs and salinity control structures proposed for construction prior to the year 2020. Runoff quantity and quality was kept the same as for the WY 1941-62 conditions. A water supply and waste water return flow plan (Table AII-1) for the year 2020, was then imposed on the system.

The model is designed to simulate mean monthly flow and quality conditions. Each month (season) is examined as a separate time frame. It is assumed that runoff from the upper most point in the model will flow to the lowermost point in the model during a single time frame, provided it is not captured in a reservoir or diverted out of the system.

Answers or model output is produced in the form of statistical information concerning the probable consequences

A

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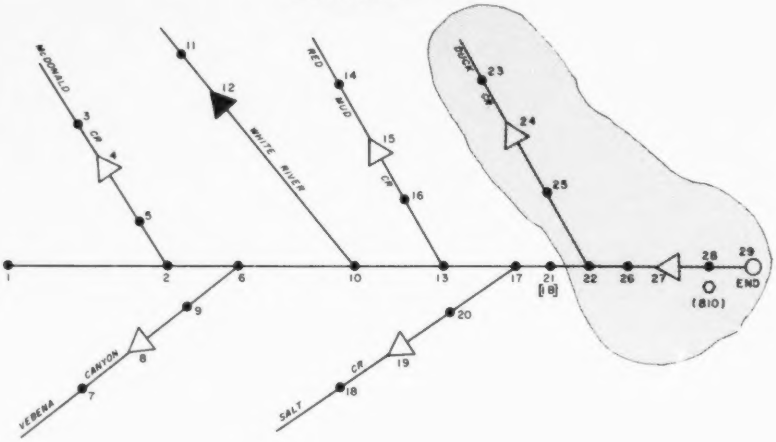

McDONALD CR
WHITE RIVER
RED MUD CR
BUCK CR
VEBENA CANYON
SALT CR
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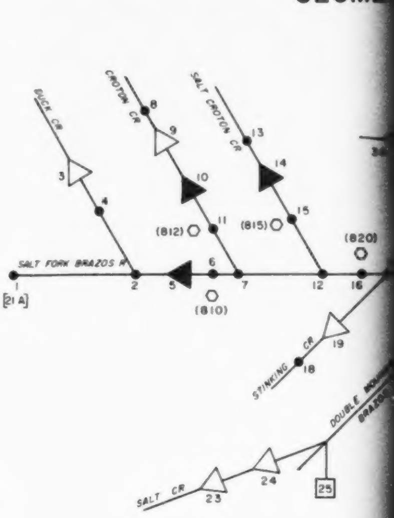

SEGME
BUCK CR
CROTON CR
SALT CROTON CR
SALT FORK BRAZOS R
STINKING CR
DOUBLE MOUN
BRAZOS
SALT CR
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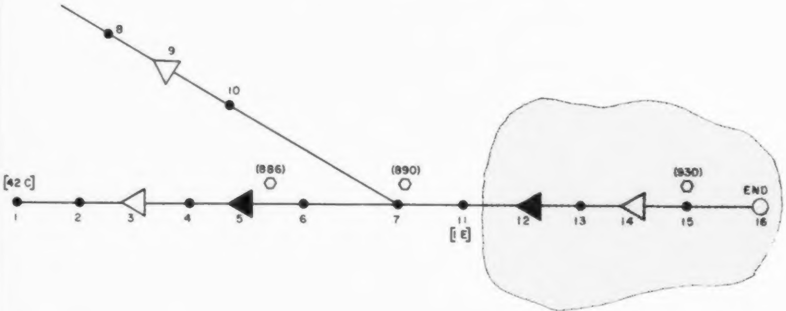

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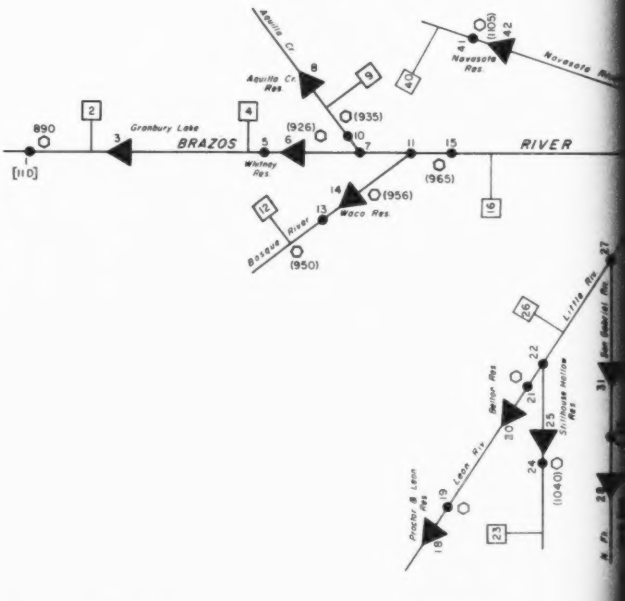

BRAZOS
RIVER
Granbury Lake
Whitney Res.
Aquilla Cr.
Aquilla Cr. Res.
Navasota Res.
Navasota Riv
Bosque River
Waco Res.
Little Riv
San Gabriel Riv
Leon Riv
Belton Res
Stillhouse Hollow Res
Proctor & Leon Res
N. Fk.
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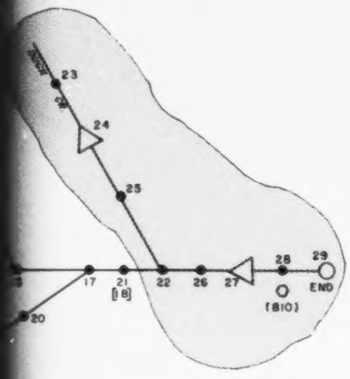
(1105)
(1040)

LEGEND

—☐	WASTE LOADING POINT
●	JUNCTION OR TEST POINT
○	U.S.G.S. STATION
(1100)	U.S.G.S. STATION NUMBER
▲	EXISTING RESERVOIR (2020 CONDITIONS)
△	PROPOSED RESERVOIR OR POSSIBLE DIVERSION
▨	OVERLAPPED STREAM REACH
[7 D]	DUPLICATE COORDINATES

B

"A"



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END
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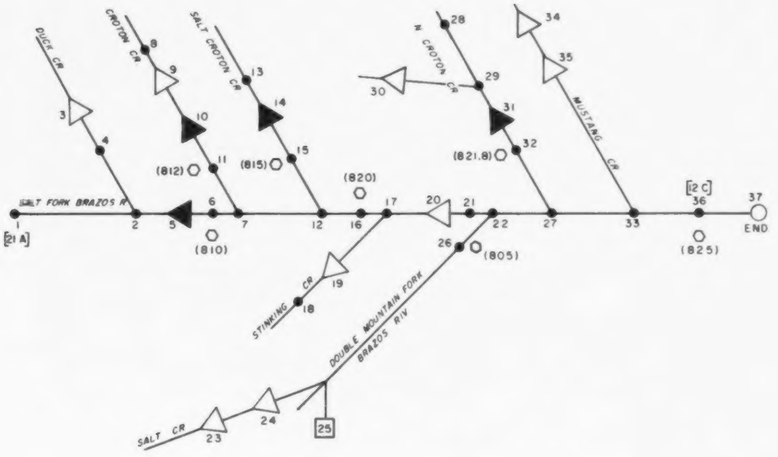

DUCK CR
CROTON CR
SALT CROTON CR
N CROTON CR
MUSTANG CR
SALT FORK BRAZOS R
STINKING CR
DOUBLE MOUNTAIN FORK BRAZOS RIV
SALT CR
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CROTON CR
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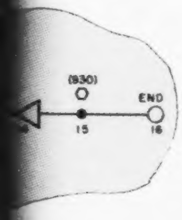
CLEAR
ELM & DE

SEGMENT "E"



(930)
15
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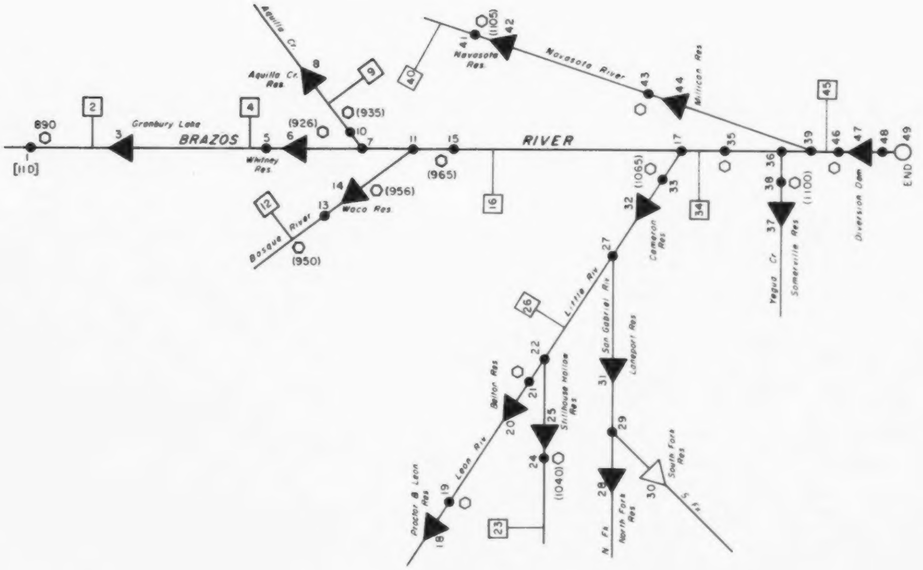
16



1
[110]
890
2
3
Granbury Lake
BRAZOS
4
5
Whitney Res.
6
(926)
Aquilla Cr.
Aquilla Cr. Res.
8
9
(935)
10
7
11
15
(965)
16
RIVER
12
Bosque River
13
14
(956)
Waco Res.
(950)
40
41
Navasota Res.
(1105)
42
Navasota River
43
44
Millican Res
17
(1065)
33
32
Cameron Res
34
35
36
38
(1100)
37
Yegua Cr
Somerville Res
45
39
46
47
Diversion Dam
48
49
END
27
Little Riv
26
San Gabriel Riv
22
21
Belton Res
20
25
Stillhouse Hollow Res
24
(1040)
23
19
Leon Riv
Proctor & Leon Res
18
31
Laneport Res
29
28
N Fk
North Fork Res
30
South Fork Res
S Fk

MODEL SEGMENT	COORDI- NATE	RES
A	4	C/E Dam Sit
	8	C/E Dam Sit
	12	White River
	15	C/E Dam Sit
	19	C/E Dam Sit
	24	C/E Dam Sit
	27	C/E Dam Sit
B	3	C/E Dam Sit
	5	C/E Dam Sit
	9	C/E Dam Sit
	10	C/E Dam Sit
	14	C/E Dam Sit
	19	C/E Dam Sit
	20	C/E Dam Sit
	23	C/E Dam Sit
	24	Substitute
	30	C/E Dam Sit
	31	C/E Dam Sit
	34	Substitute
	35	Substitute

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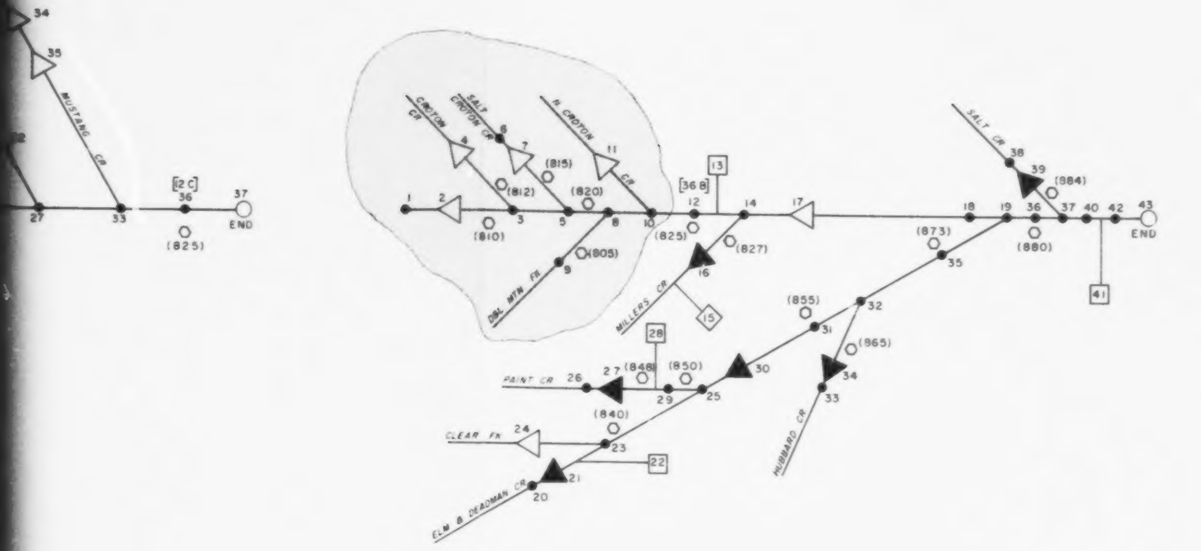
a/ A single reservoir has been u

ITIONS)

SEGMENT "C"



34
35
MUSTANG CR
32
27
33
[2C]
36
37
END
(825)
CROTON CR
SALT CROTON CR
N CROTON
CR
1
2
3
4
5
6
7
8
9
10
11
12
13
14
(812)
(815)
(820)
(810)
(805)
DBL MTN FK
[36 B]
(825)
(827)
16
15
MILLERS CR
17
SALT CR
38
39
(884)
18
19
36
37
40
42
43
END
(880)
41
(873)
35
32
(855)
31
(865)
30
34
33
HUBBARD CR
28
(848)
(850)
PAINT CR
26
27
29
25
(840)
CLEAR FK
24
23
22
21
20
ELM & DEADMAN CR

45
39
46
47
48
49
END
(1100)
Diversion Dam
Yegua Cr
Somerville Res

MODEL SEGMENT	COORDI-NATE	RESERVOIR
A	4	C/E Dam Site 1
	8	C/E Dam Site 2
	12	White River
	15	C/E Dam Site 23
	19	C/E Dam Site 4
	24	C/E Dam Site 24
	27	C/E Dam Site 20
B	3	C/E Dam Site 24
	5	C/E Dam Site 20
	9	C/E Dam Site 25
	10	C/E Dam Site 10
	14	C/E Dam Site 14
	19	C/E Dam Site 16
	20	C/E Dam Site 18
	23	C/E Dam Site 22
	24	Substitute for Test Point
	30	C/E Dam Site 27
	31	C/E Dam Site 19
	34	Substitute for Test Point
	35	Substitute for Test Point
C	2	White River
	4	C/E Dam Site 10
	7	C/E Dam Site 14
	11	C/E Dam Site 19
	16	Millers Creek
	17	Potential Diversion Dam
	21	a/ Fort Phantom Hill (Sweetwater, Abilene, Kirby, Cisco)
	24	Diversion Dam
	27	Stamford
	30	Breckenridge
	34	Hubbard Lake
	39	Lake Graham
D	3	Substitute for Test Point
	5	a/ Possum Kingdom Lake (Palo Pinto Ck., Mineral Wells)
	9	Potential Off-Stream Storage
	12	a/ Lake Granbury (Pat Cleburne)
	14	Lake Whitney
E	3	Lake Granbury
	6	Lake Whitney
	8	Aquilla Creek
	14	a/ Waco Lake (Stephenville)
	18	a/ Proctor Lake (Leon)
	20	Belton Lake
	24	Stillhouse Hollow Lake
	28	North San Gabriel Lake
	30	South San Gabriel Lake
	31	Laneport
	32	Cameron
	37	Somerville Lake
	42	Navasota 2
	44	Millican
	47	Diversion Dam

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a/ A single reservoir has been used in the model to represent the affect of a combined group. Storage volumes are added.

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

BRAZOS RIVER BASIN
SIMULATION MODEL SCHEMATIC

ENVIRONMENTAL PROTECTION AGENCY

REGION VI
DALLAS, TEXAS

FIGURE AII-1

TABLE A II-1

WATER SUPPLY AND WASTE WATER RETURN FLOW PLAN a/
BRAZOS RIVER BASIN SIMULATION MODEL
(2020 CONDITIONS)

Area	2020 Requirement AF/YR	Ground Water AF/YR	Surface Water AF/YR	Model Coordinate Groundwater Return Flow	Model Coordinate Surface Water Return Flow	Reservoir	Diversion Number	Notes
White River	3,600		3,600		10A	White River	1	
Sub-Area 1					25B	(Out of Basin)		b/
Seymour	1,149		1,149		14C	Millers-Elm Cr.	1	
Benjamin	120	120		13C				
Munday	631		631		14C	Millers-Elm Cr.	1	
Baylor Co. Other	24	24		13C				
Haskell Co. Other	1,436	1,436		13C				
Knox Co. Other	326	326		13C				
Olney	1,753		1,753		14C	Millers-Elm Cr.	1	
Young Co. Other	6,350		6,350		14C	Millers-Elm Cr.	1	
Haskell	1,436		1,436		29C	Millers-Elm Cr.	2	
Anson	1,701		1,701		29C	Millers-Elm Cr.	2	
Irrigation	12,000		12,000		18C	Div. Dam Coord. 17	1	
Young Co. Other	1,750		1,750		18C	Div. Dam Coord. 17	1	
Abilene	11,300		11,300		23C	Ft. Phantom, Hill	1	c/
Sweetwater	1,700		1,700		23C	Sweetwater		c/
Sweetwater	2,400		2,400		23C	Oak Cr. (Ft. Phantom H.)		c/
Nolan Co. Other	285	285		22C				
Stamford	600		600		29C	Stamford	1	b/
Hamlin	1,532	1,532		28C				
Haskell Co. Other	1,435	1,435		28C				
Throckmorton	432		432		18C	Breckenridge	2	
Young Co. Other	10,758	5,358	5,400	13C	18C	Breckenridge	2	
Abilene	31,900		31,900		23C	Breckenridge	1	
Sweetwater	6,200		6,200		23C	Breckenridge	1	
Stamford	1,835		1,835		29C	Breckenridge	3	
Albany	789		789		18C	Breckenridge	2	
Shackelford Co. Other	379		379		18C	Breckenridge	2	
Abilene	11,900		11,900		23C	Hubbard Creek	1	
Fisher Co. Other	118	118		22C				
Breckenridge	3,000		3,000		40C	Hubbard Creek	2	
Eastland Co. Other	26	26		41C				
Stevens Co. Other	122	122		41C				
Scurry Co. Other	1,323	1,323		41C				
Graham	6,400		6,400		37C	Graham Reservoir	1	
Graham	2,100		2,100		37C	Possum Kingdom	2	d/
Steven Co. Other	59	59		41C				
Ranger	1,229	1,229		2E				
Eastland Co. Other	21	21		2E				
Jack Co. Other	77	77		2E				
Parker Co. Other	539	539		2E				
Mineral Wells	10,085		10,085		1E	DeCordova Bend	3	
Palo Pinto Co. Other	1,533		1,533		1E	DeCordova Bend	3	
Granbury	798		798		5E	DeCordova Bend	2	
Hood Co. Other	124	124		4E				
Johnson Co. Other	1,462		1,462		5E	DeCordova Bend	2	
Glen Rose	394	394		4E				
Somerville Co. Other	64	64		4E				
Cleburn	12,756		12,756		5E	DeCordova Bend	2	
McGregor	4,322	1,249	3,073	12E	13E	Whitney	2	
Waco	40,100		40,100		15E	Whitney (PK)	1	
Waco	20,000		20,000		15E	Whitney (PK)	1	
McLennan Co. Other	13,239		13,239		15E	Whitney (PK)	1	
Marlin	3,498		3,498		15E	Whitney (PK)	1	
Falls Co. Other	1,061		1,061		15E	Whitney (PK)	1	
McLennan Co. Other	4,021		4,021		15E	Whitney (PK)	1	
Irrigation	50,985		50,985		15E	Whitney (PK)	3	
Hillsboro	5,366		5,366		10E	Aquilla	2	
Hill Co. Other	498	498		9E				
Meridian	907	907		12E				

TABLE A II-1 (Continued)

Area	2020 Requirement AF/YR	Ground Water AF/YR	Surface Water AF/YR	Model Coordinate Groundwater Return Flow	Model Coordinate Surface Water Return Flow	Reservoir	Diversion Number	Notes
Bosque Co. Other	224	224		12E				
Coryell Co. Other	17	17		12E				
Stephenville	6,885	2,000	4,800	12E	13E	Waco	1	
Erath Co. Other	403	403		12E				
Hamilton Co. Other	52	52		12E				
Irrigation	31,250		31,250		13E	Waco	3	
Bellmead	11,806		11,806		15E	Waco	2	
Waco	45,587		45,587		15E	Waco	2	
Hearne	3,010	3,010		16E				
Robertson Co. Other	874	874		16E				
Comanche Co. Other	537	537		26E				
Gatesville	2,372		2,372		19E	Proctor	2	
Coryell Co. Other	96	96		26E				
Erath Co. Other	227	227		26E				
Hamilton	1,161	1,161		26E				
Hamilton Co. Other	116	116		26E				
Eastland Co. Other	200	200		26E				
Comanche	2,031		2,031		19E	Proctor	2	
McLennan Co. Other	226	226		26E				
Eastland	2,133		2,133		19E	Proctor	2	
Irrigation	4,600		4,600		19E	Proctor	3	
Cisco	1,454		1,454		19E	Proctor	1	e/
Waco	25,000		25,000		15E	Belton	1	
Belton	5,913		5,913		21E	Belton	2	
Kileen	12,277		12,277		21E	Belton	2	
Copperas Cove	3,030		3,030		21E	Belton	2	
Temple	22,409		22,409		21E	Belton	2	
Irrigation	11,500		11,500		21E	Belton	3	
Burnet	472	472		23E				
Lampasas	3,400		3,400		23E	Stillhouse Hollow	2	f/
Lampasas Co. Other	215		215		23E	Stillhouse Hollow	2	f/
Bell Co. Other	5,476	3,776	1,700	26E	22E	Stillhouse Hollow	2	
Irrigation	31,000		31,000		22E	Stillhouse Hollow	3	
Georgetown	4,609		4,609		29E	N. San Gabriel	2	
Irrigation	6,500		6,500		29E	N. San Gabriel	3	
Taylor	4,798		4,798		27E	Laneport	2	
Irrigation	8,900		6,037		27E	Laneport	3	
Irrigation			2,885		27E	Cameron	3	
Williamson Co. Other	1,796	1,796		26E				
Cameron	2,200		2,200		33E	Cameron	2	
Milam Co. Other	422		422		33E	Cameron	2	
Lee Co. Other	147		147		39E	Somerville	2	
Freestone Co.	123	123		40E				
Leon Co. Other	90	90		40E				
Mexia	3,671		3,671		40E	(Trinity Basin)		
Limestone Co. Other	1,206	1,206		40E				
Teague	954	954		40E				
Bryan	31,886	20,000	11,886	34E	35E	Millican	1	
College Station	12,444	5,000	7,500	34E	35E	Millican	1	
Caldwell	991	991		34E				
Burleson Co. Other	471	471		34E				
Milam Co. Other	258	258		34E				
Brazos Co. Other	380		380		39E	Millican	2	
Navasota	1,447		1,447		39E	Millican	2	
Grimes Co. Other	186		186		39E	Millican	2	
Walker Co. Other	101	101		45E				
Brenham	4,381	4,381		45E				
Washington Co. Other	2,414	2,414		45E				
Rockdale	4,167	4,167		45E				
Bellville	2,870	2,870		45E				

TABLE A II-1 (Continued)

Area	2020 Requirement AF/YR	Ground Water AF/YR	Surface Water AF/YR	Model Coordinate Groundwater Return Flow	Model Coordinate Surface Water Return Flow	Reservoir	Diversion Number	Notes
Washington Co. Other	598	598		45E				
Austin Co. Other	1,030	1,030		45E				
Hempstead	5,728	5,728		45E				
Walker Co. Other	1,170	1,170		45E				
Rosenberg	25,068	25,068		45E				
Richmond	17,181	17,181		45E				
Fort Bend Co. Other	3,600	3,600		45E				
Coastal	829,900		829,900		45E	Diversion Dam	1	g/

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a/ This distribution of supply only includes an account of surface water resources that contribute to the main stem resources above Richmond. It does not include possible imports from East Texas.

b/ Resource to basin is represented by return flow of 40,688 AF/YR introduced at waste site 1 Coordinate 25 of model segment 'B'. No other sub-area 1 conditions are included in the basin model.

c/ Only 11,300 AF/YR is drafted from Fort Phantom Hill Reservoir. Return flow is increased to represent waste returned from Sweetwater area generated from Sweetwater and Oak Creek Reservoir supplies.

d/ Due to the segmentation of the basin model, diversion of 2100 AF/YR could not be returned to the Graham area. This quantity is drafted from P.K. with zero return flow. Return to system is represented by increasing the quantity of return flow from diversion at Lake Graham.

e/ Due to the segmentation of the basin model, diversion of 1454 AF/YR could not be returned to the Cisco area. This quantity is drafted from Proctor with zero return flow. Return to system is represented by waste returned at waste site 5 Coordinate 41 in model segment 'C'.

f/ The 3615 AF/YR requirement is drafted by diversion two. No waste is returned. Model limitation of only three diversions made this representation necessary.

g/ San Jacinto-Brazos (Brazos System)

San Jacinto-Brazos (Brazos System)		
	Irrigation	332,700
	Municipal and Industrial	413,600
		746,300
San Jacinto-Brazos (Houston System)		
	Municipal and Industrial	83,600
Total Diversion		829,900

of the implementation of proposals under study. Consequences evaluated are water quality, streamflow and reservoir levels. The model yields statistical moments and probability distributions of these consequences.

Model Operation

The 2020 model with salinity control plans 4A and 4B was operated to satisfy surface water demands specified in Table AII-1. Since only three explicit withdrawals (diversions) could be made from a single reservoir, it was often necessary to specify one withdrawal for satisfying the combined needs of a large area. The quantity and quality of each diversion was modified to represent conversion of the water supply to waste water (Table AII-2). The waste water was then returned to the system for use further downstream.

The quality of municipal and industrial waste water was generated by arbitrarily increasing the concentration of water supply mineral constituents as follows: chloride 75 mg/1; sulfate 30 mg/1 and total dissolved-solids 222 mg/1. Irrigation water supply concentrations were tripled to represent waste water concentrations. Where groundwater supplies were used, the quality of the supply was estimated and the procedure described above was used to convert the supply to waste water. Waste water from use of groundwater supplies is injected into the system at waste loading points (Table AII-3).

Basically local surface water needs are supplied by reservoirs closest to the point of demand. Supplies surplus to local demands are systematically moved downstream through the main stem of the Brazos River to points of heavy demand. Demands in the lower basin below the mouth of the Navasota River are satisfied first from resources above the Little River system and uncontrolled runoff, then from the Little River system, and then from the Navasota River system.

TABLE AII-2

SURFACE WATER DISTRIBUTION [a]
WATER SUPPLY AND WASTE WATER RETURN FLOW PLAN
BRAZOS RIVER BASIN SIMULATION MODEL
(2020 CONDITIONS)

	SURFACE WATER DISTRIBUTION						SEASONAL DIVERSION QUANTITY (cfsm) [b]												
Reservoir	Reservoir Coordinate	Return Flow Coordinate	Model Diversion Number	Annual Diversion (AF)	Fraction Diversion Returned	Annual Return Flow (AF)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Diversion (cfsm)
White River	12A	10A	1	3,600	0.00	0	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	59.64
Millers Creek	16C	14C	1	9,883	0.56	5,534	15.55	9.66	10.31	8.68	8.02	8.68	9.17	9.49	16.70	22.75	22.75	21.94	163.70
	16C	29C	2	3,137	0.49	1,537	4.94	3.07	3.27	2.75	2.55	2.75	2.91	3.01	5.30	7.22	7.22	6.96	51.95
Diversion Dam	17C	18C	3	13,750	0.17	2,338	4.42	5.06	0.57	0.64	1.89	6.33	6.97	9.50	30.38	86.07	56.94	18.99	227.76
Fort Phantom Hill	21C	23C	2	11,300	0.57	6,441	12.54	11.04	10.85	10.48	9.73	12.16	12.72	15.22	21.52	25.82	26.95	17.59	187.12
Stamford	27C	29C	2	600	0.46	276	0.94	0.59	0.63	0.53	0.49	0.53	0.56	0.58	1.01	1.38	1.38	1.33	9.95
Breckenridge	30C	23C	1	38,100	0.48	18,288	42.28	37.23	36.60	35.34	32.82	41.02	42.91	53.01	72.58	87.09	90.88	59.32	631.08
	30C	18C	2	7,000	0.46	3,220	7.77	6.84	6.73	6.49	6.03	7.54	7.88	9.74	13.33	16.00	16.70	10.90	115.95
	30C	29C	3	1,835	0.45	826	2.04	1.79	1.76	1.70	1.58	1.98	2.07	2.55	3.49	4.19	4.38	2.86	30.39
Hubbard Lake	34C	23C	1	11,900	0.49	5,831	13.21	11.63	11.43	11.04	10.25	12.81	13.40	16.56	22.67	27.20	28.38	18.53	197.11
	34C	40C	2	3,000	0.51	1,530	3.33	2.93	2.88	2.78	2.58	3.23	3.38	4.17	5.71	6.86	7.16	4.67	49.68
Graham	39C	37C	2	6,400	0.73	4,672	10.07	6.25	6.68	5.62	5.19	5.61	5.94	6.15	10.81	14.74	14.74	14.21	106.01
Possum Kingdom Lake	5D	6D	2	2,100	0.00	0	3.30	2.05	2.19	1.84	1.70	1.84	1.94	2.01	3.54	4.83	4.83	4.66	34.73
Lake Granbury	3E	5E	2	15,016	0.61	9,160	17.90	14.50	14.70	14.50	12.90	14.90	16.10	19.40	27.50	36.60	36.60	22.80	248.40
	3E	1E	3	11,618	0.60	6,971	13.86	11.16	11.35	11.16	10.0	11.74	12.51	16.01	21.36	28.29	28.29	17.70	192.43
Lake Whitney	6E	15E	1	81,919	0.54	44,236	97.69	78.70	80.05	78.70	70.56	82.77	88.20	105.84	150.62	199.47	199.47	124.83	1356.90
	6E	13E	2	3,073	0.56	1,721	3.66	2.95	3.00	2.95	2.64	3.10	3.30	3.97	5.65	7.48	7.48	4.68	50.86
	6E	15E	3	50,985	0.19	9,687	30.47	4.96	0.40	0.00	18.20	16.97	13.58	58.22	236.28	330.36	94.91	40.16	844.51
Aquilla Creek	8E	10E	2	5,366	0.60	3,220	7.02	6.04	5.95	5.69	5.24	5.51	6.40	7.64	8.44	11.82	11.20	7.91	88.86
Waco Lake	14E	13E	1	4,800	0.59	2,832	5.72	4.61	4.69	4.61	4.13	4.84	5.16	6.20	8.82	11.68	11.68	7.31	79.45
	14E	15E	2	57,393	0.56	32,140	68.45	55.14	56.09	55.14	49.43	57.99	61.79	74.15	105.52	139.75	139.75	87.46	950.66
	14E	13E	3	31,250	0.20	6,250	2.69	0.88	0.36	0.57	1.71	12.37	13.04	19.57	118.43	191.78	133.24	22.98	517.62
Proctor Lake	18E	19E	1	1,454	0.00	0	1.76	1.32	1.25	1.08	1.06	1.16	1.30	1.61	2.96	4.12	4.12	2.34	24.08
	18E	19E	2	6,536	0.50	3,268	7.90	5.95	5.63	4.87	4.76	5.19	5.85	7.25	13.32	18.51	18.51	10.50	108.24
	18E	19E	3	4,600	0.20	920	1.95	0.77	0.12	0.15	0.30	2.41	3.10	6.80	21.34	27.05	9.62	2.52	76.13
Belton Lake	20E	15E	1	25,000	0.57	14,250	29.82	24.02	24.43	24.02	21.53	25.26	26.92	32.30	45.97	60.87	60.87	38.10	414.11
	20E	21E	2	43,629	0.51	22,251	52.03	41.92	42.64	41.92	37.58	44.08	46.97	56.37	80.22	106.24	106.24	66.49	722.70
	20E	21E	3	11,500	0.20	2,300	4.90	1.94	0.32	0.38	0.76	6.04	7.77	17.01	53.36	67.64	24.06	6.30	190.48
Stillhouse Hollow Lake	25E	22E	2	5,315	0.16	850	6.33	5.10	5.19	5.10	4.57	5.37	5.72	6.87	9.78	12.94	12.94	8.07	87.98
	25E	22E	3	31,000	0.20	6,200	13.20	5.24	0.87	1.03	2.05	16.26	20.95	45.85	143.83	182.34	64.85	16.00	512.47
North San Gabriel Lake	28E	29E	2	4,609	0.46	2,120	5.50	4.43	4.50	4.43	3.97	4.66	4.96	5.95	8.47	11.22	11.22	7.02	76.33
	28E	29E	3	6,500	0.20	1,300	2.76	1.09	0.18	0.22	0.43	3.41	4.39	9.61	30.16	38.23	13.60	3.56	107.64
Laneport	31E	27E	2	4,798	0.55	2,639	6.68	5.09	4.53	5.01	4.61	4.69	5.56	5.56	7.23	9.30	12.24	8.98	79.48
	31E	27E	3	6,037	0.20	1,207	2.57	1.02	0.17	0.20	0.40	3.17	4.08	8.93	28.01	35.51	12.63	3.31	100.00
Cameron	32E	33E	2	2,622	0.51	1,337	3.65	2.78	2.48	2.74	2.52	2.56	3.04	3.04	3.95	5.08	6.68	4.91	43.43
	32E	27E	3	2,885	0.20	577	1.23	0.48	0.08	0.01	0.19	1.52	1.95	4.28	13.44	17.04	6.06	1.58	47.86
Somerville Lake	37E	39E	2	147	0.00	0	0.20	0.16	0.14	0.15	0.14	0.14	0.17	0.17	0.22	0.28	0.37	0.27	2.41
Millican	44E	35E	1	19,386	0.50	9,693	28.50	24.01	24.33	23.05	21.13	24.01	23.05	27.21	28.50	33.62	34.26	28.50	320.17
	44E	39E	2	2,013	0.50	1,006	2.97	2.50	2.53	2.40	2.20	2.50	2.40	2.83	2.97	3.50	3.56	2.97	33.33
Diversion Dam	47E	48E	1	829,900	0.00	0	1145.54	1145.54	1145.54	1145.54	1145.54	1145.54	1145.54	1145.54	1145.54	1145.54	1145.54	1145.54	13746.48

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[a] This distribution of supply only includes an account of surface water resources that contribute to the main stem resources above Richmond. It does not include possible imports from East Texas. Water requirements in sub-areas 1 and 2 are not fully satisfied.

[b] Cubic feet per second month (cfsm) X 60.37 = Acre Feet.

TABLE A II-3

GROUNDWATER RETURN FLOW
WATER SUPPLY AND WASTE WATER RETURN FLOW PLAN
BRAZOS RIVER BASIN SIMULATION MODEL
(2020 CONDITIONS)

GROUNDWATER		SEASONAL RETURN FLOW (cfsm) d/												
Return Flow Coordinate	Return Flow (AF/YR)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Return Flow (cfsm)
25B	40687 a/	34.37	31.68	33.02	38.42	49.87	87.61	99.07	112.55	63.35	45.82	41.79	36.39	673.94
13C	3213	2.82	2.61	2.82	2.98	3.09	5.43	7.40	7.40	7.13	5.05	3.14	3.35	53.22
22C	136	0.13	0.12	0.15	0.15	0.19	0.26	0.31	0.32	0.21	0.15	0.13	0.13	2.25
28C	1379	1.28	1.19	1.48	1.55	1.92	2.63	3.15	3.29	2.15	1.53	1.35	1.32	22.84
41C	1409 b/	1.31	1.21	1.52	1.59	1.96	2.68	3.23	3.36	2.19	1.56	1.38	1.35	23.34
2E	1055	1.01	0.90	1.07	1.14	1.36	1.94	2.57	2.57	1.61	1.26	1.01	1.03	17.47
4E	353	0.34	0.30	0.36	0.38	0.45	0.65	0.86	0.86	0.54	0.42	0.34	0.34	5.84
9E	431	0.46	0.42	0.44	0.51	0.61	0.68	0.95	0.90	0.64	0.56	0.49	0.48	7.14
12E	2892	2.78	2.49	2.92	3.11	3.74	5.32	7.04	7.04	4.41	3.45	2.78	2.83	47.91
16E	3756	4.03	3.43	3.72	3.85	4.06	5.36	6.65	7.06	6.28	6.77	6.32	4.68	62.21
23E	211	0.20	0.18	0.21	0.23	0.27	0.39	0.52	0.52	0.32	0.25	0.20	0.21	3.50
26E	4123	3.96	3.55	4.17	4.44	5.33	7.58	10.04	10.04	6.28	4.92	3.96	4.03	68.30
34E	13282	13.86	12.76	12.98	15.40	15.40	20.02	25.74	33.88	24.86	18.48	14.08	12.54	220.00
40E	2621 c/	2.73	2.52	2.56	3.04	3.04	3.95	5.08	6.68	4.91	3.65	2.78	2.47	43.41
45E	57073	37.83	34.83	35.43	42.04	54.65	420.00	70.26	92.48	67.86	50.44	38.43	34.23	978.48

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a/ Includes return from 37,700 AF/YR surface water supply.
b/ Includes return from 1,454 AF/YR surface water from Proctor Reservoir.
c/ Includes return from 3,671 AF/YR surface water supply.
d/ Cubic feet per second month (cfsm) X 60.37 = Acre Feet.

Reservoir Rules

Each reservoir is operated according to specified rules. Brief descriptions of the rules are presented below. The typical operation for a reservoir is as follows:

1. The current inflow and start of the season storage are added and the quality of the contents blended.
2. The evaporation loss or rainfall addition is then considered and the quality re-constituted.
3. The required diversions are then withdrawn from the total assets.
4. Specified releases are made.
5. Resources in excess of capacity or conservation storage is spilled.
6. When a test site is encountered where a target flow has been specified, releases are made from designated reservoirs to supply supplemental needs.

NOTE: (Refer to Table AII-2 for Diversions)

White River (Coord. 12A)

a. Local demands are withdrawn by diversion No. 1.

b. Excess above capacity is spilled.

Corps of Engineers Dam Site 20 (Coord. 5B)

a. Excess above capacity could be spilled. However, the reservoir is sized so that no spills occur. This reservoir was deleted for Plan 4B.

Corps of Engineers Dam Site 10 (Coord. 10B)

a. Pump a maximum quantity water of 11 cfsm to Corps of Engineers Dam Site 19.

Pump only the quantity Dam Site 19 will hold without spilling. If possible, pump all water out of Dam Site 10.

b. Excess above capacity could be spilled.

Corps of Engineers Dam Site 14 (Coord. 14B)

a. Pump a maximum quantity water of 18 cfsm to Corps of Engineers Dam Site 19. Pump only the quantity Dam Site 19 will hold without spilling. If possible, pump all water out of Dam Site 14.

b. Excess above capacity could be spilled.

Corps of Envineers Dam Site 19 (Coord. 31B)

a. Excess above capacity could be spilled.

Diversion Dam (Coord. 17C)

a. Diversion No. 3 is made to meet local demands.

Millers Creek (Coord. 16C), Fort Phantom Hill (Coord. 21C), Stamford (Coord. 27C), Breckenridge (Coord. 30C), Hubbard (Coord. 34C, and Graham (Coord. 39C)

a. Diversions Nos. 1, 2, and 3 are made in sequence to meet local demands. Reservoirs can be drafted down to dead storage.

b. Excess above capacity will be spilled.

Possum Kingdom Lake (Coord. 5D)

a. Divert a maximum quantity water of 500 cfsm to Coordinate D6. Divert only the quantity Granbury Lake will hold without spilling. Only divert when Possum Kingdom storage is above 9200 cfsm.

b. Diversion No. 2 is made to meet local demands.

c. Excess above capacity will be spilled.

Lake Granbury (Coord. 3E)

a. Divert a maximum quantity water of 500 cfsm to Whitney Lake. Divert only the quantity Whitney Lake will hold without spilling. Only divert when Lake Granbury storage is above 1200 cfsm.

b. Diversions Nos. 2 and 3 are made to meet local demands.

c. Excess above capacity will be spilled.

Whitney Lake (Coord. 6E)

a. Diversions Nos. 1, 2, and 3 are made in sequence to meet local demands. Reservoirs can be drafted down to dead storage.

b. Excess above conservation pool level will be spilled.

c. A monthly (seasonal) target flow of 342 cfsm was set at Coordinate 7E. This target is equal to the expected annual supply the basin above this point will provide. Releases are made first from Whitney Lake and then from Aquilla to meet this target. Targets are also set further downstream at Coordinate 46E. Whitney Lake can be drafted to meet these targets also if the lower basin cannot supply demands below Coordinate 7E.

Proctor Lake (Coord. 18E)

a. Diversions Nos. 1, 2, and 3 are made in sequence to meet local demands. Reservoirs can be drafted down to dead storage.

b. Excess above conservation pool level will be spilled.

c. A monthly (seasonal) target flow of 7 cfsm was set at Coordinate 19E. This target is equal to the expected annual yield that is excess to local demands. Releases are made seasonally to meet this target. Resources are moved downstream.

Belton Lake (Coord. 20E)

a. Diversions Nos. 1, 2, and 3 are made in sequence to meet local demands. Reservoir can be drafted down to dead storage.

b. Excess above conservation pool level will be spilled.

c. A monthly (seasonal) target flow of 128 cfsm was set at Coordinate 22E. This target is equal to the expected annual supply the basin above this point will provide. Releases are made first from Belton Lake and then from Stillhouse Hollow Lake to meet this target. Another target of 141 cfsm was set at Coordinate 27E. Releases are made first from Stillhouse Hollow and then from Belton to meet this target.

Stillhouse Hollow Lake (Coord. 24E)

a. Divert a maximum quantity water of 300 cfsm to Coordinate 22E. Divert only the quantity Cameron will hold without spilling. Only divert when Stillhouse Hollow Lake storage is above 1000 cfsm.

b. Diversions Nos. 2 and 3 are made to meet local demands.

c. Excess above conservation pool level will be spilled.

d. A monthly (seasonal) target flow of 128 cfsm was set at Coordinate 22E. Releases are made first from Belton Lake and then from Stillhouse Hollow Lake to meet this target. Another target of 141 cfsm was set at Coordinate 27E. Releases are made first from Stillhouse Hollow and then from Belton to meet this target.

North San Gabriel Lake (Coord. 28E), Laneport (Coord. 31E)

a. Diversions Nos. 2 and 3 are made in sequence to meet local demands. Reservoir can be drafted down to dead storage.

b. Excess above conservation pool level will be spilled.

Cameron (Coord. 32E)

a. Diversions Nos. 2 and 3 are made in sequence to meet local demands. Reservoir can be drafted down to dead storage.

b. Excess above conservation pool level will be spilled.

c. A monthly (seasonal) target flow of 270 cfsm was set at Coordinate 33E. This target is equal to the expected annual supply the basin above this point will provide. Releases are made from Cameron Reservoir to meet this target. A second target of 763 cfsm is set at Coordinate 35E. When main stem resources cannot meet this target releases are made from Cameron (Little River system). A third target of 1285 cfsm is set at Coordinate 39E to be satisfied by releases from Millican then Cameron. A fourth target of 1335 cfsm is set at Coordinate 46E to be satisfied by releases from Cameron, Whitney Lake and then Millican.

Somerville Lake (Coord. 37E)

a. Diversion No. 2 is made to meet local demands. Reservoir can be drafted down to dead storage.

b. Excess above conservation pool level will be spilled.

c. A monthly (seasonal) target flow of 49 cfsm was set at Coordinate 38E. This target is equal to the expected annual yield that is excess to local demands. Releases are made seasonally to move resources downstream.

Navasota 2 (Coord. 42E)

a. Divert a maximum quantity water of 3000 cfsm to Coordinate 43E. Pump only the quantity Millican will hold without spilling. Only divert when Navasota storage is above 6000 cfsm.

b. Excess above conservation storage will be spilled.

Millican (Coord. 44E)

a. Diversions Nos. 1 and 2 are made to meet local demands.

b. Excess above conservation storage will be spilled.

c. A monthly (seasonal) target flow of 1285 cfsm was set at Coordinate 39E. If the basin above this point does not supply adequate resources to meet this target, then releases are made first from Millican and then Cameron to satisfy the target. A second target of 1335 cfsm is set at Coordinate 46E to be satisfied by releases from Cameron, Whitney Lake and then Millican.

Diversion Dam (Coord. 47E)

a. Diversion No. 1 is made to meet demands in the San-Jacinto Brazos Coastal Basin service area.

APPENDIX III

ALTERNATIVE PLAN 4B

Project Description

Alternative Plan 4B involves construction of only three of the reservoirs included in Plan 4A. Plan 4B does not include the reservoir at Dam Site 20 on the main stem of the Salt Fork Brazos River (See Figures III-1 and III-2). All reservoirs in Plan 4B are located on tributaries. Site 10 is located on Croton Creek, site 14 is on Salt Croton Creek and site 19 is on North Croton Creek. The reservoirs at sites 10 and 14 will be used only for collection and temporary storage. Water collected in these reservoirs will be pumped into site 19 for permanent storage. The reservoir at site 14 will be dry much of the time. All three reservoirs are adequately sized to prevent passage of any surface flow past the dam sites.

Water Quality Control (Plan 4B)

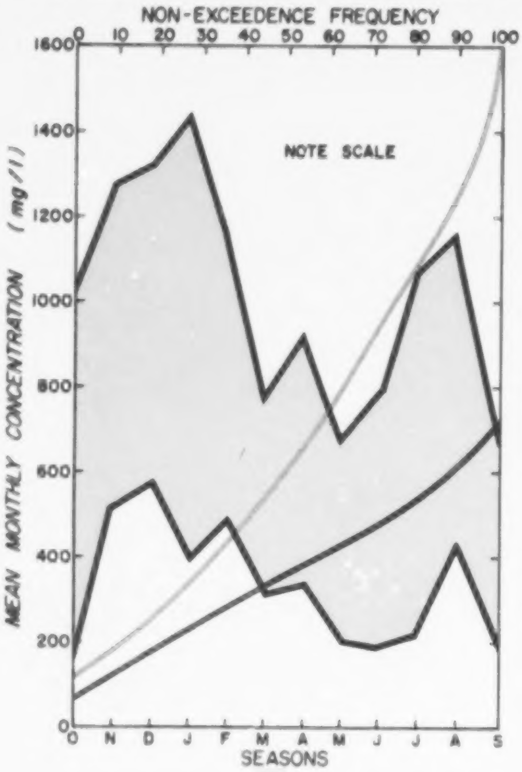
Figures AIII-1, AIII-2, and AIII-3 graphically depict the projected quality of water resources in the main stem of the Brazos River after the Plan 4B salinity control project is in place and the year 2020 water supply and waste water return flow plan (Appendix II) is operating. Quality curves for Plan 4A are also shown for comparison. The graphs do not reflect improvements in quality conditions that will accrue from reduction of pollution from oil production. Graphs are shown on each figure to describe the quality condition expected at five locations - USGS (stream gage and quality) Station No. 825 Brazos River at Seymour, Texas; USGS (stream gage) Station No. 890 Brazos River near Palo Pinto 20 miles downstream from Possum Kingdom Dam; USGS (stream gage) Station No. 965 Brazos River at Waco, Texas, 2 1/2 miles downstream from the Bosque River; USGS (stream gage and quality) Station No. 1090 Brazos River near Bryan, Texas; USGS (stream gage and quality) Station No. 1140 Brazos River at Richmond, Texas, river mile 93.

Table AIII-1 presents values excerpted from the graphs and predictions of future quality conditions.

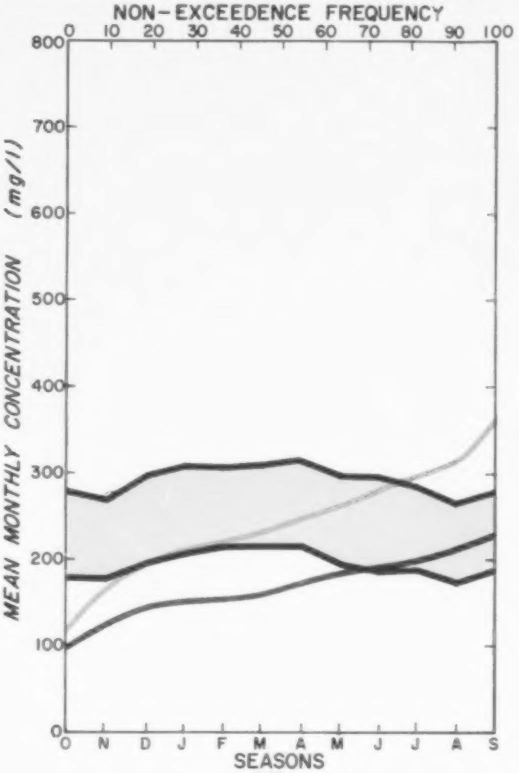
If the quality of water expected at Station No. 825 is measured with the potability scale (Table VIII-4), the quality would range from fair to unacceptable and would

A

USGS STATION No. 825



USGS STATION No. 890

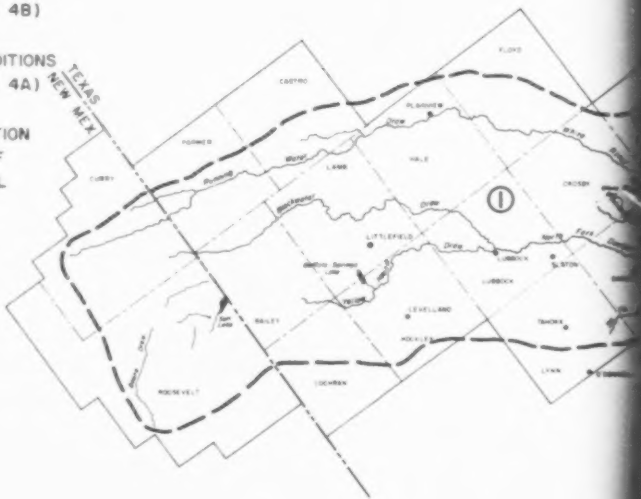


LEGEND

NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL (PLAN 4B)

NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL (PLAN 4A)

▨ RANGE OF MEAN MONTHLY CONCENTRATIONS ONE STANDARD DEVIATION ABOVE AND BELOW THE MEAN CONCENTRATION FOR THE PERIOD OF RECORD ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL


TEXAS
NEW MEX
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FLOYD
PARMER
PLAINVIEW
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CURRY
Running
Water
LAMB
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CROSBY
Blackwater
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①
LITTLEFIELD
Draw
LUBBOCK
North Fork
SLATON
LUBBOCK
BAILEY
LEVELLAND
HOCKLEY
TAHOKA
LYNN
COCHRAN
ROOSEVELT

NOTE: WATER YEARS 1941-62 STREAMFLOW RECORDS WERE USED FOR SIMULATION OF MATHEMATICAL MODEL FLOW

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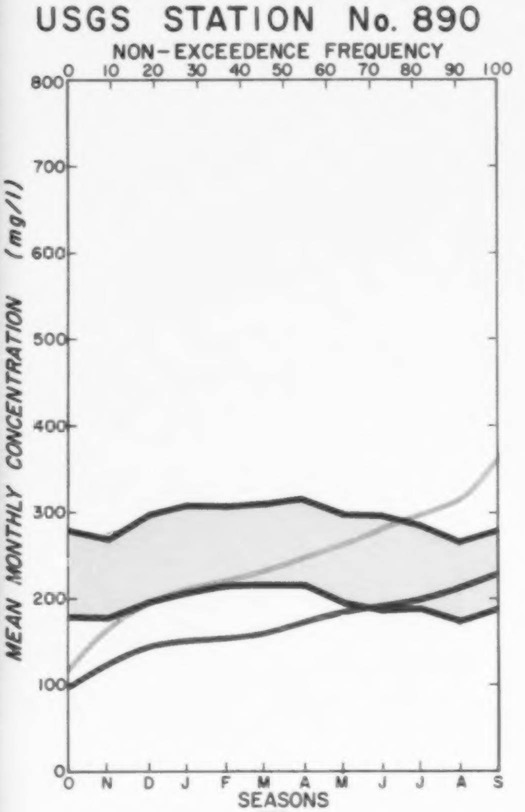

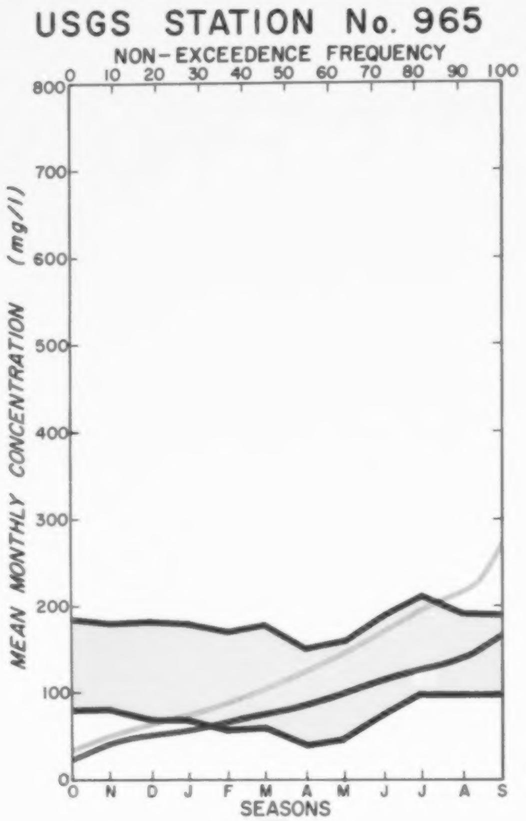

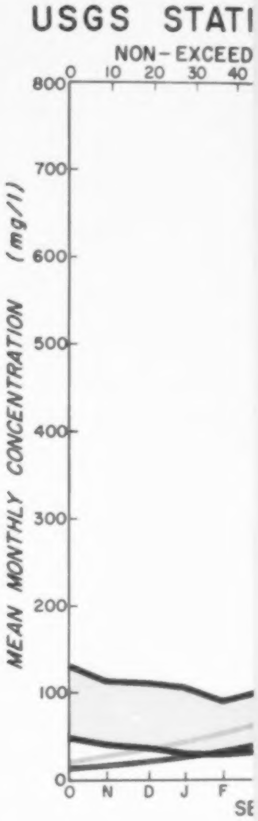

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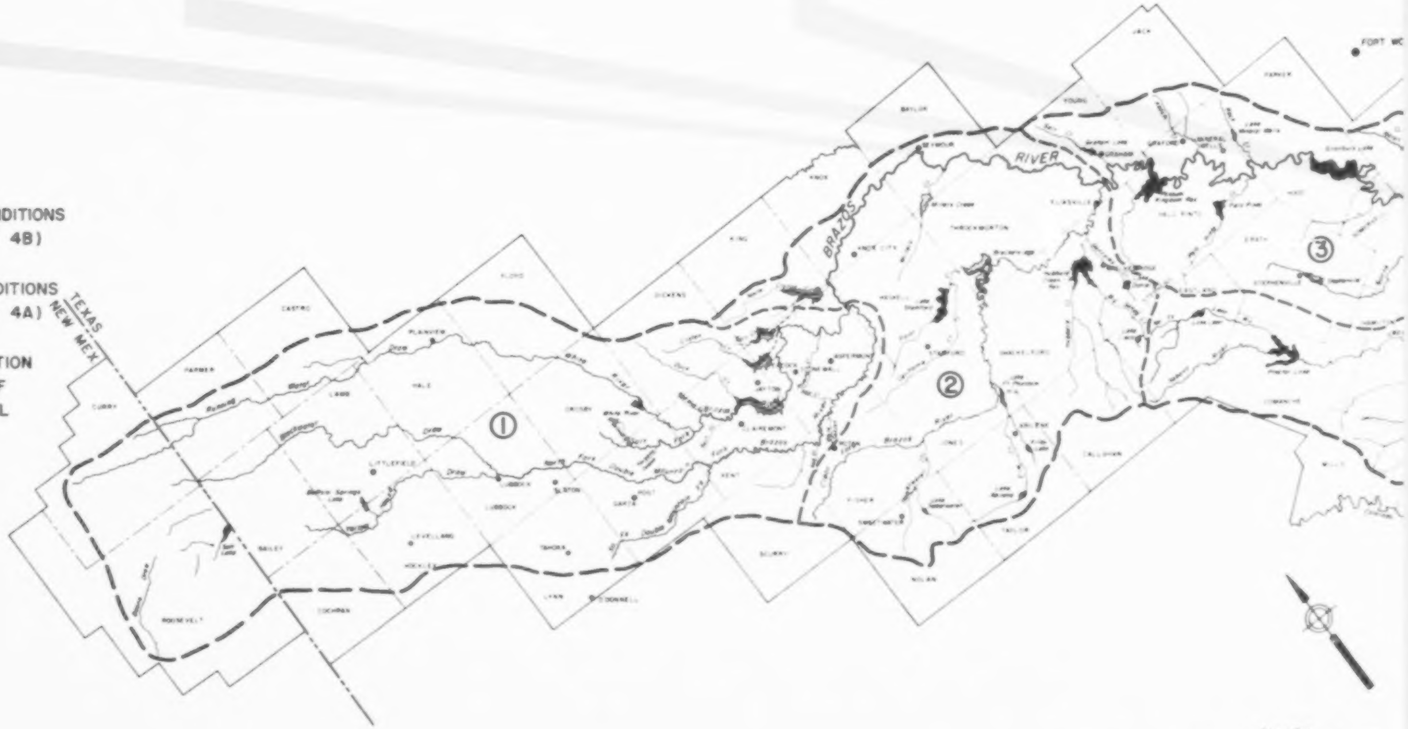

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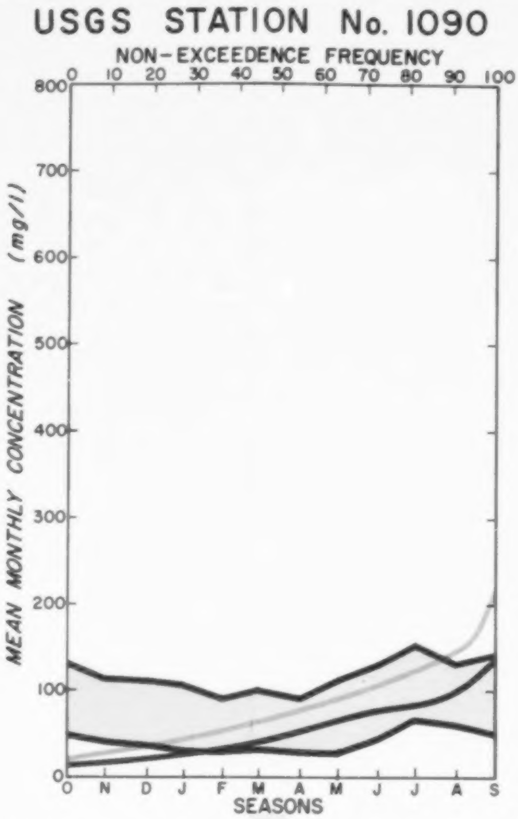

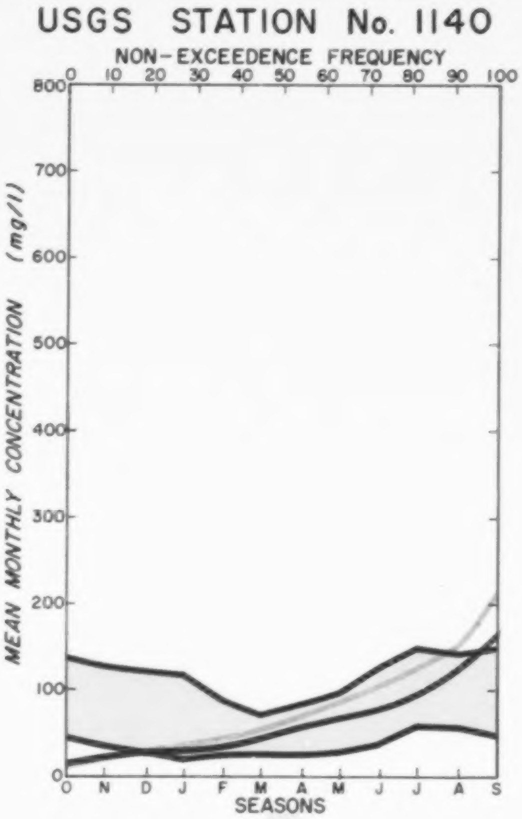

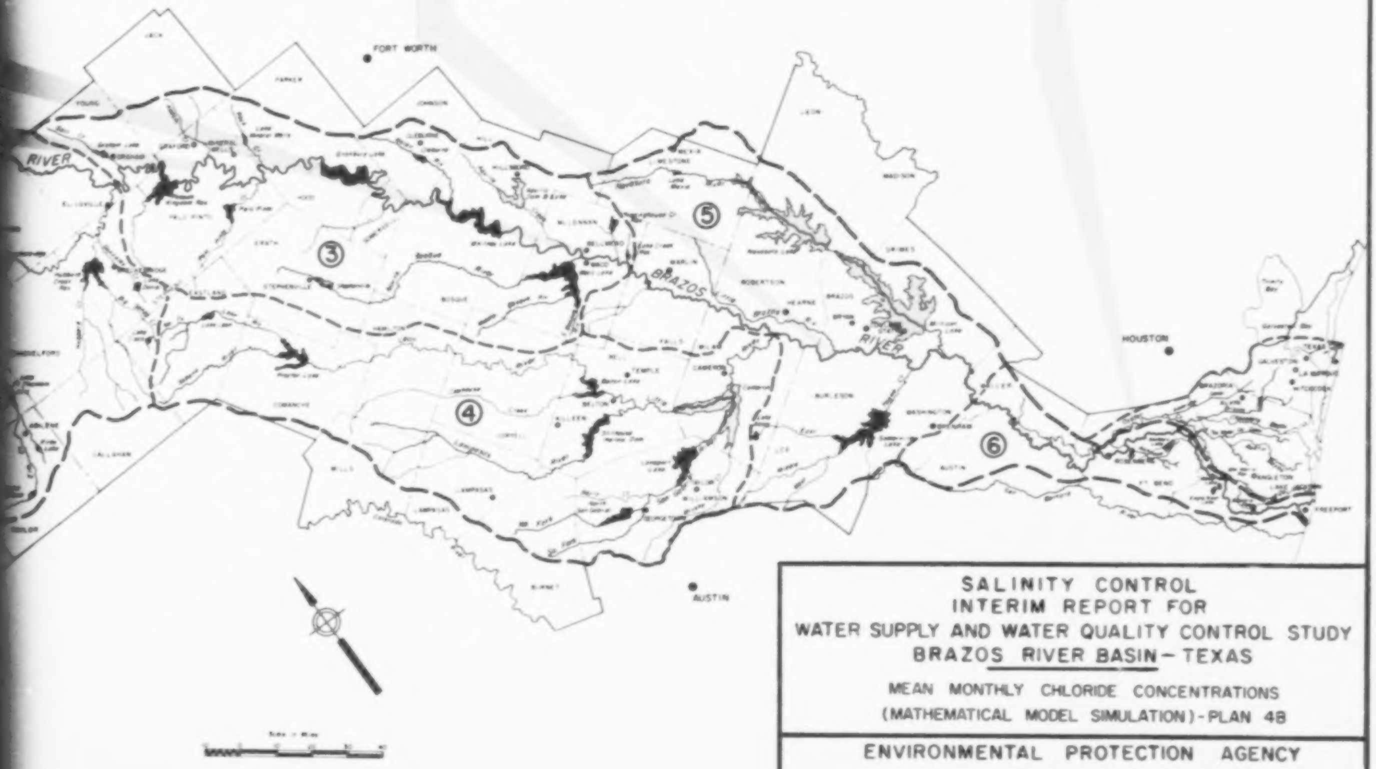
FORT WORTH
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TEMPLE
BELTON
KILLEEN
COMANCHE
CALLAHAN
MILLS
LAMPASAS
BURNET
LEON
MADISON
GRIMES
ROBERTSON
BURLESON
WASHINGTON
AUSTIN
HOUSTON
FT. BEND
FREEPORT
GALVESTON
AUSTIN

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

MEAN MONTHLY CHLORIDE CONCENTRATIONS
(MATHEMATICAL MODEL SIMULATION) - PLAN 4B

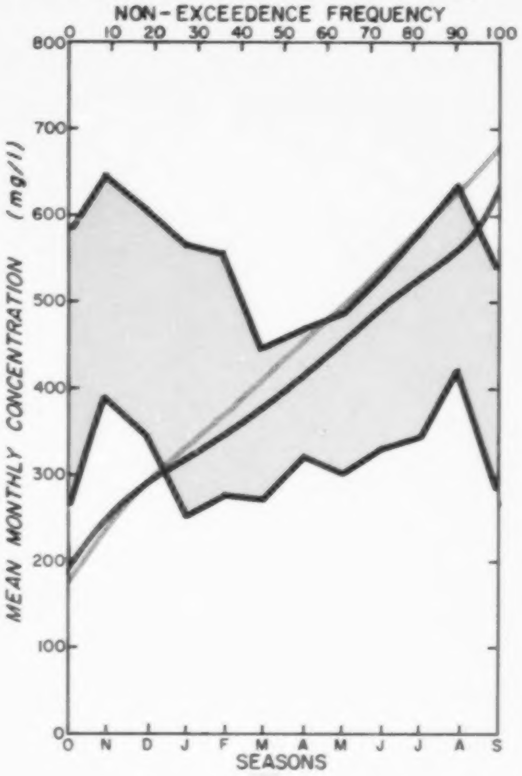
ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE AIII-1

A

USGS STATION No. 825



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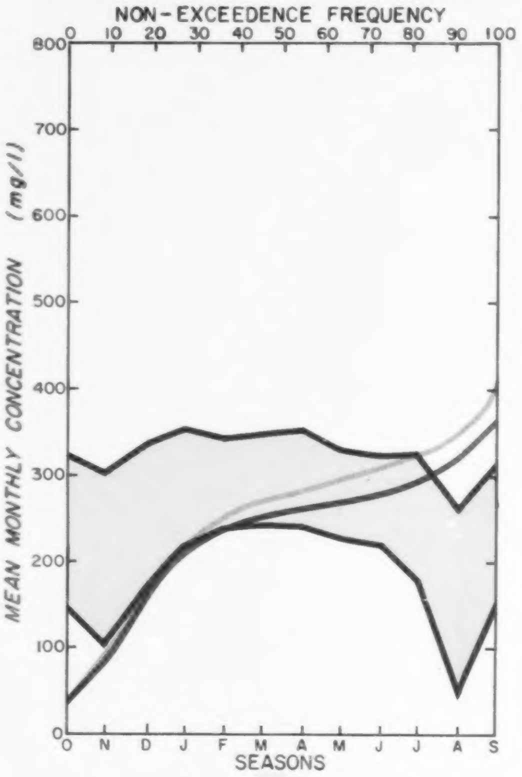

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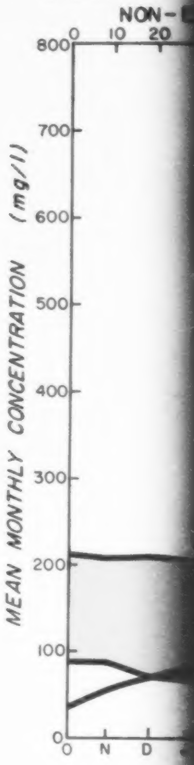
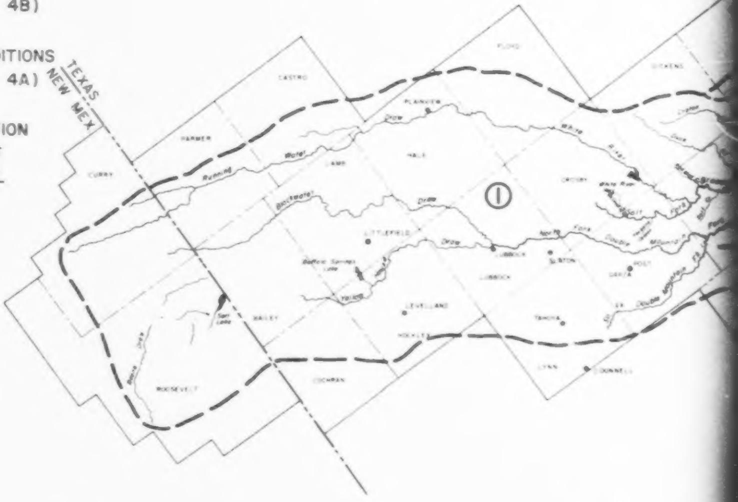


LEGEND

— NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL (PLAN 4B)

— NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL (PLAN 4A)

▨ RANGE OF MEAN MONTHLY CONCENTRATIONS ONE STANDARD DEVIATION ABOVE AND BELOW THE MEAN CONCENTRATION FOR THE PERIOD OF RECORD ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL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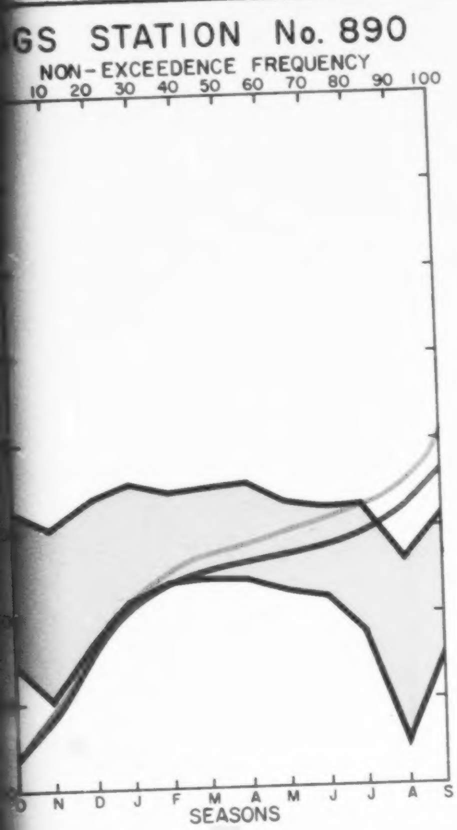
HOCKLEY
TAHOKA
LYNN
O'DONNELL
COCHRAN
ROOSEVELT
Double Mountain Fork

NOTE: WATER YEARS 1941-62 STREAMFLOW RECORDS WERE USED FOR SIMULATION OF MATHEMATICAL MODEL FLOW



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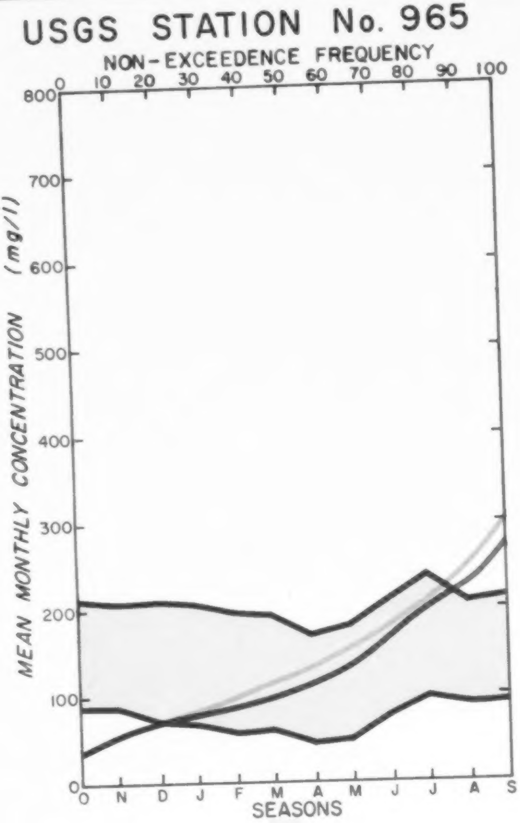

USGS STATION No. 965
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800
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MEAN MONTHLY CONCENTRATION (mg/l)
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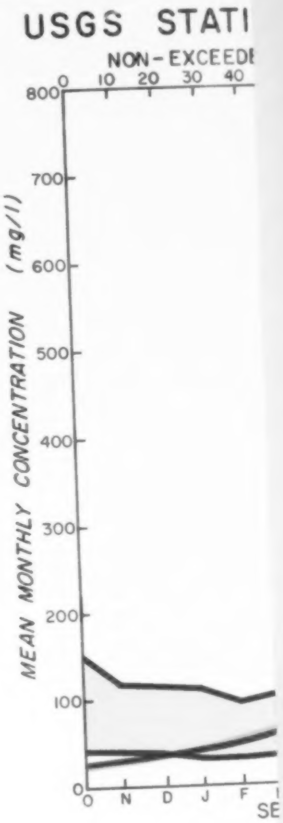

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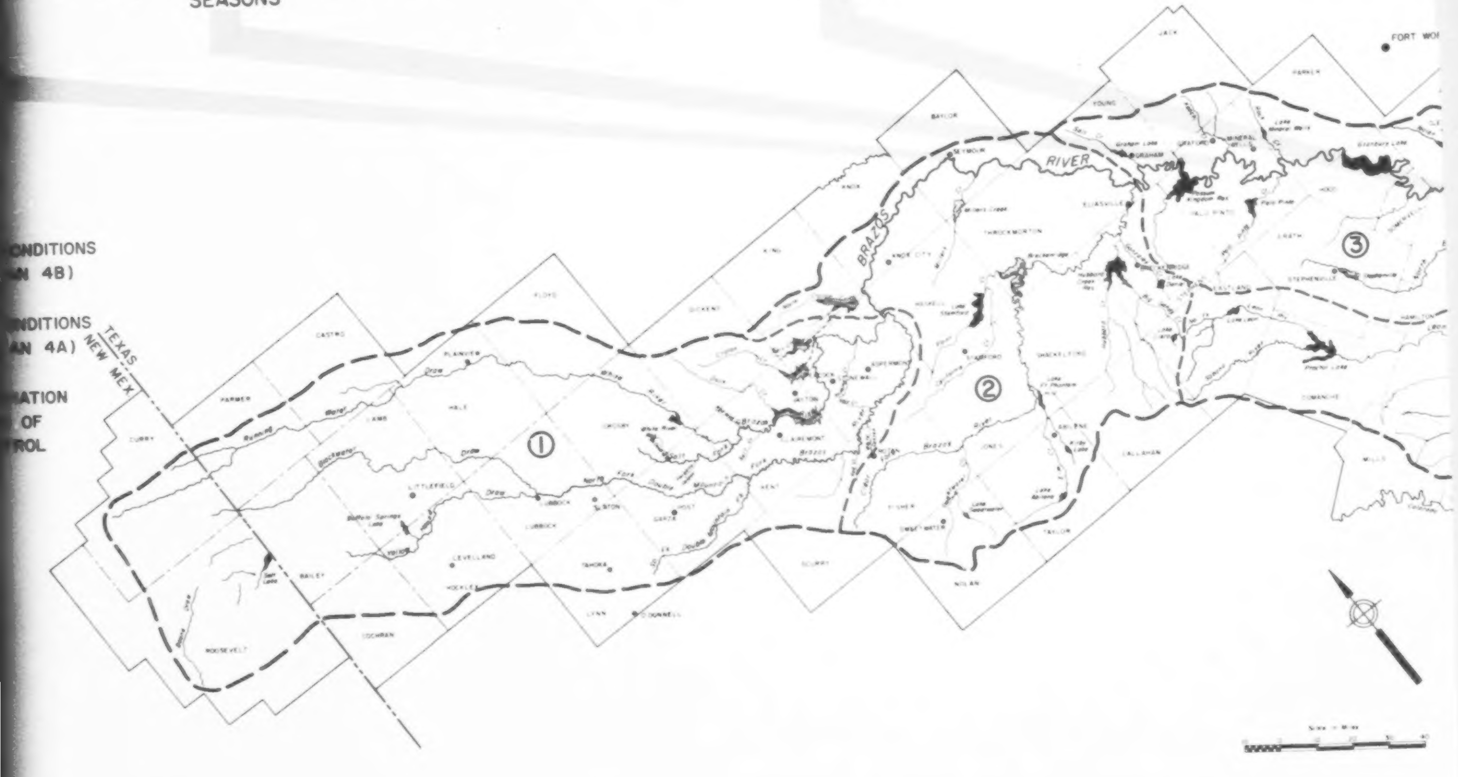

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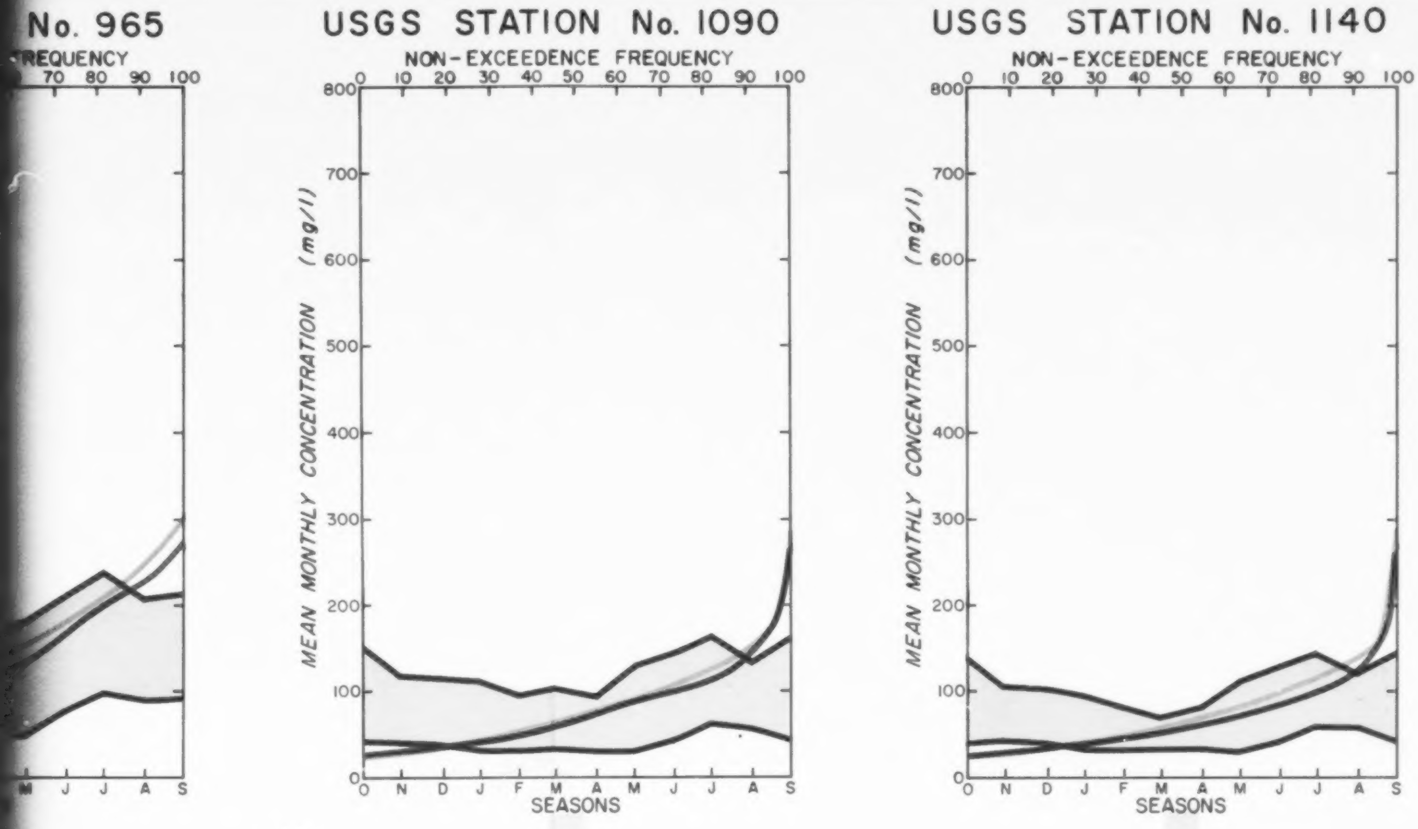
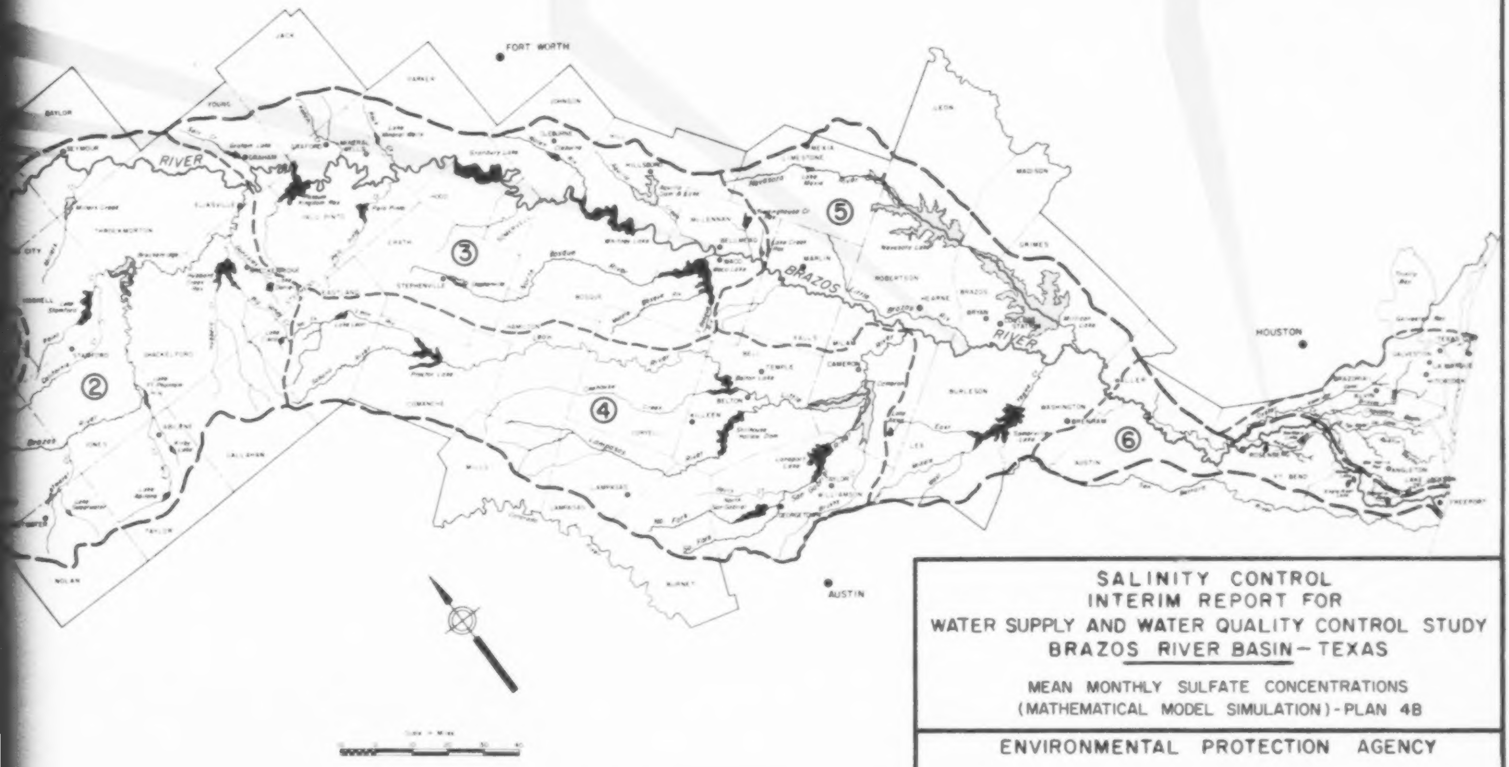
HALE
FLOYD
DICKENS
CROSBY
PLAINVIEW
LITTLEFIELD
LUBBOCK
SLATON
POST
GARZA
LEVELLAND
HOCKLEY
TAHOKA
LYNN
O'DONNELL
BAILEY
COCHRAN
ROOSEVELT
KENT
KING
KNOX
BAYLOR
SEYMOUR
KNOX CITY
THROCKMORTON
HASKELL
STAMFORD
SHACKELFORD
JONES
ABILENE
FISHER
SWEETWATER
SCURRY
NOLAN
TAYLOR
CALLAHAN
ELIASVILLE
YOUNG
JACK
GRAHAM
GRAFORD
MINERAL WELLS
PARKER
PALO PINTO
ERATH
HOOD
STEPHENVILLE
EASTLAND
COMANCHE
HAMILTON
MILLS
FORT WORTH
Proctor Lake
Possum Kingdom Res.
Hubbard Creek Res.
Lake Stamford
Buffalo Springs Lake
Scale in Miles




FORT WORTH
RIVER
BRAZOS
RIVER
HOUSTON
AUSTIN
FREEPORT
②
③
④
⑤
⑥

SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

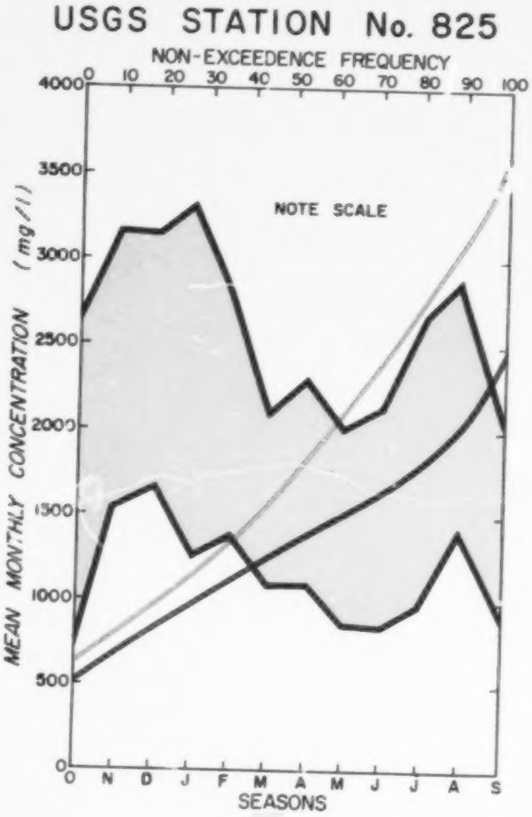
MEAN MONTHLY SULFATE CONCENTRATIONS
(MATHEMATICAL MODEL SIMULATION) - PLAN 4B

ENVIRONMENTAL PROTECTION AGENCY

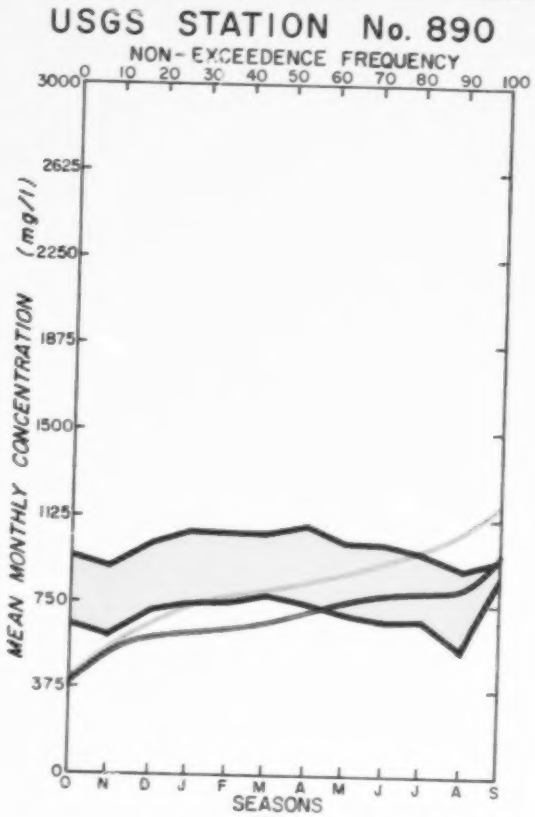
REGION VI DALLAS, TEXAS

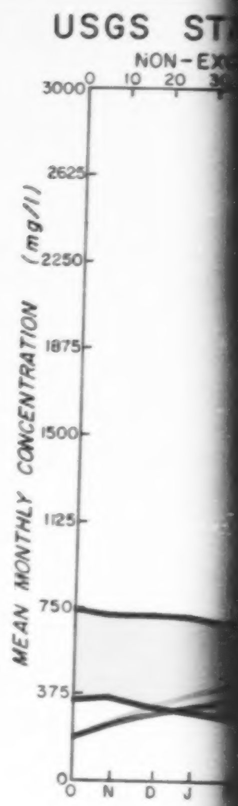
FIGURE AIII-2

A


USGS STATION No. 825

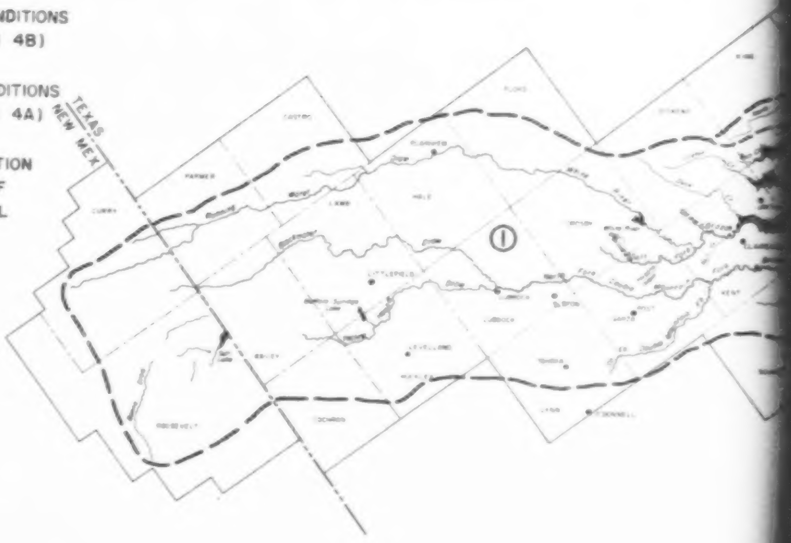
B


USGS STATION No. 890


USGS ST

LEGEND

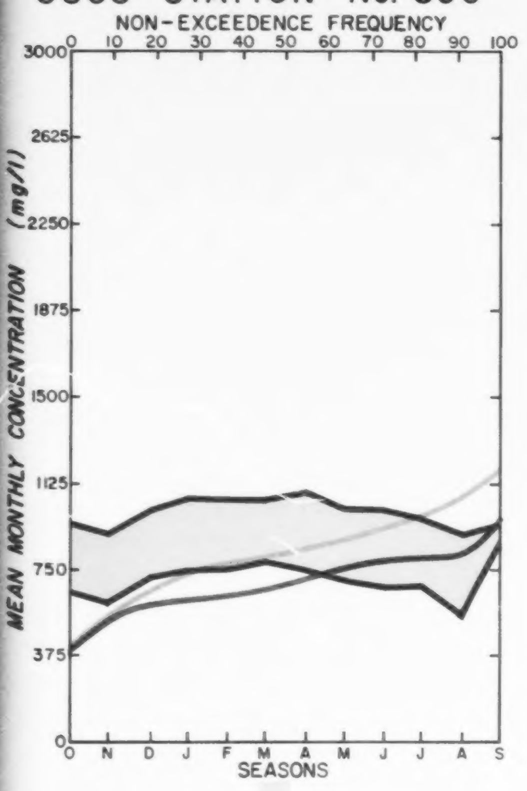
▭	NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL (PLAN 4B)
▭	NON-EXCEEDENCE FREQUENCY CURVE REPRESENTING QUALITY CONDITIONS ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL (PLAN 4A)
▨	RANGE OF MEAN MONTHLY CONCENTRATIONS ONE STANDARD DEVIATION ABOVE AND BELOW THE MEAN CONCENTRATION FOR THE PERIOD OF RECORD ASSUMING 2020 BASIN DEVELOPMENT WITH SALT CONTROL



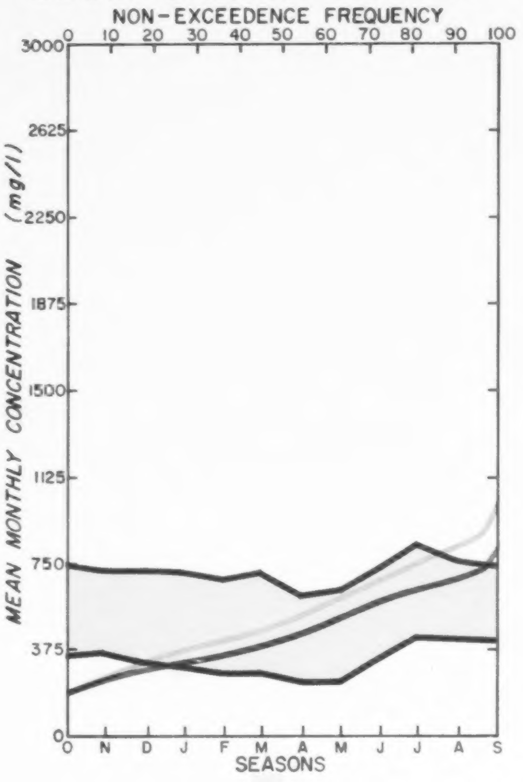
NOTE: WATER YEARS 1941-62 STREAMFLOW RECORDS WERE USED FOR SIMULATION OF MATHEMATICAL MODEL FLOW

B

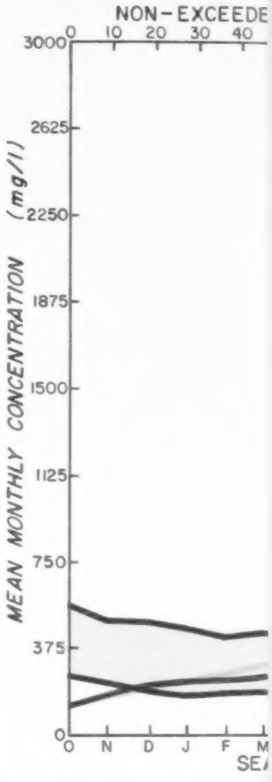
USGS STATION No. 890



USGS STATION No. 965



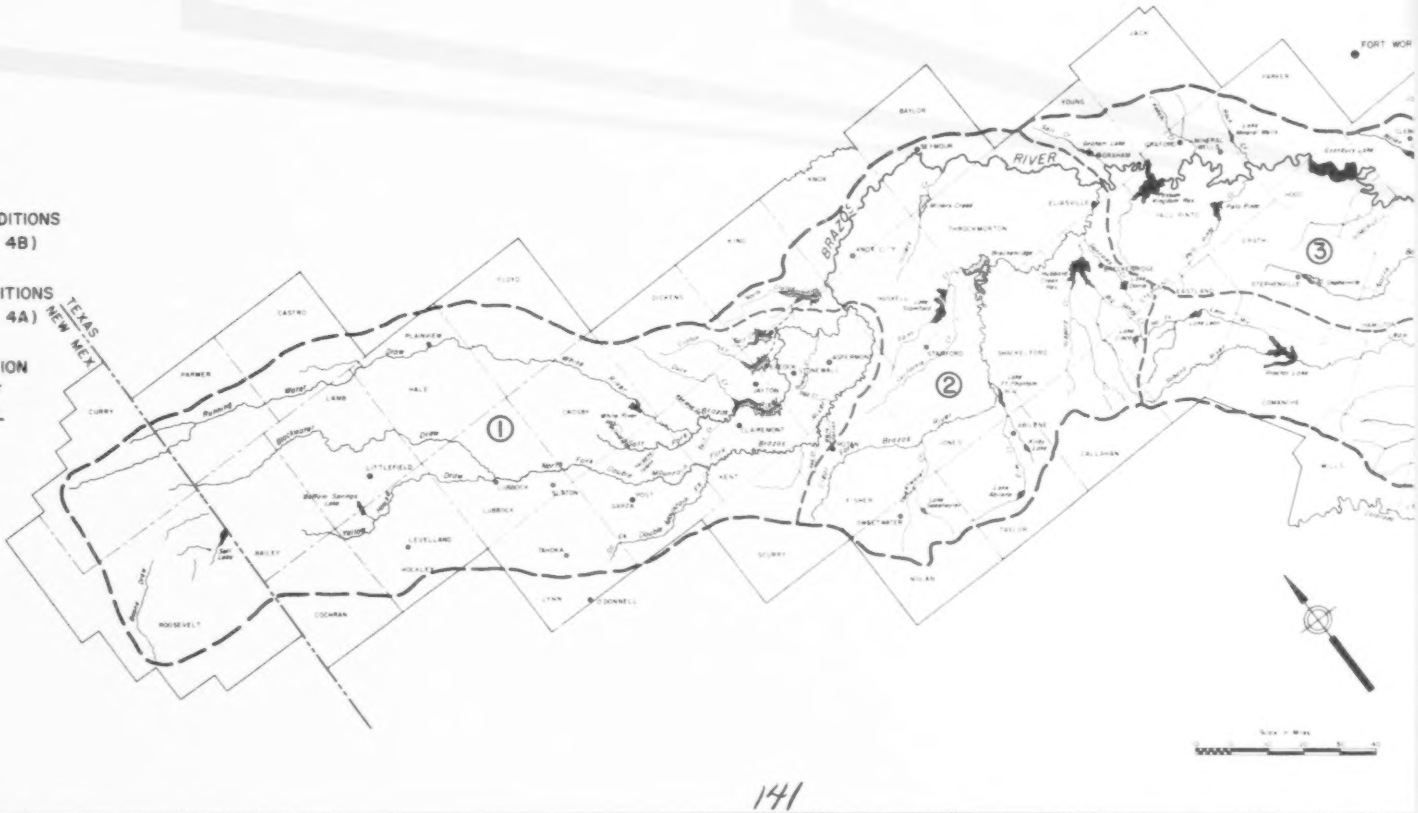
USGS STATI



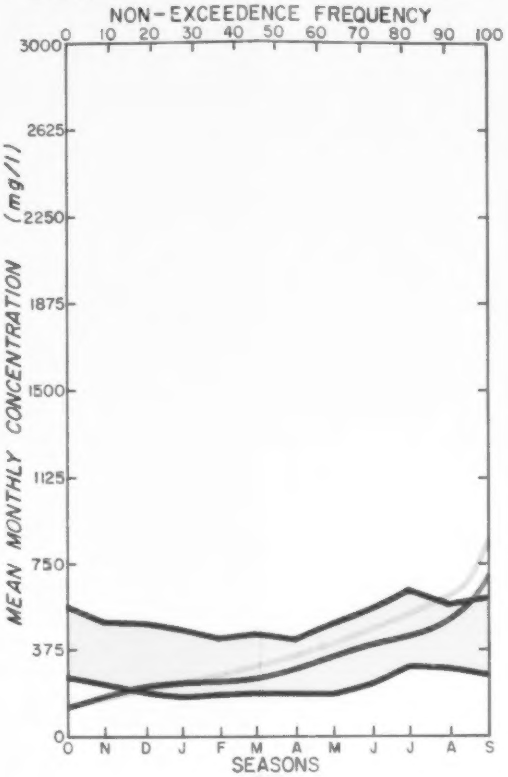
LITY CONDITIONS
(PLAN 4B)

ITY CONDITIONS
(PLAN 4A)

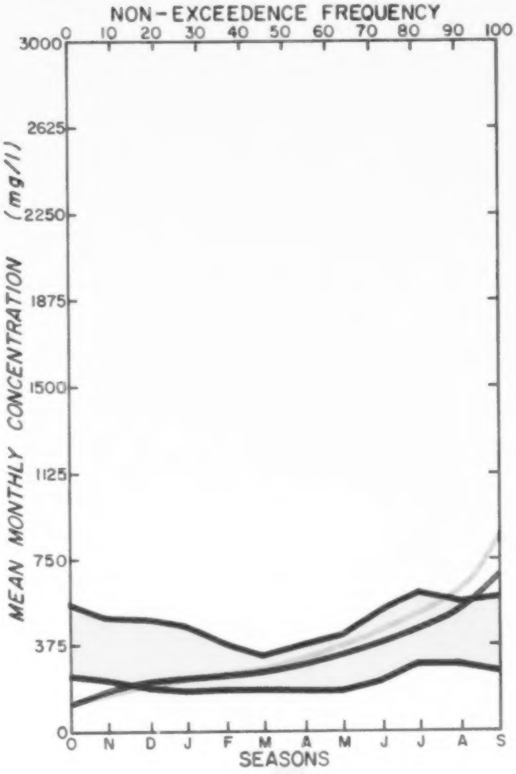
D DEVIATION
PERIOD OF
CONTROL

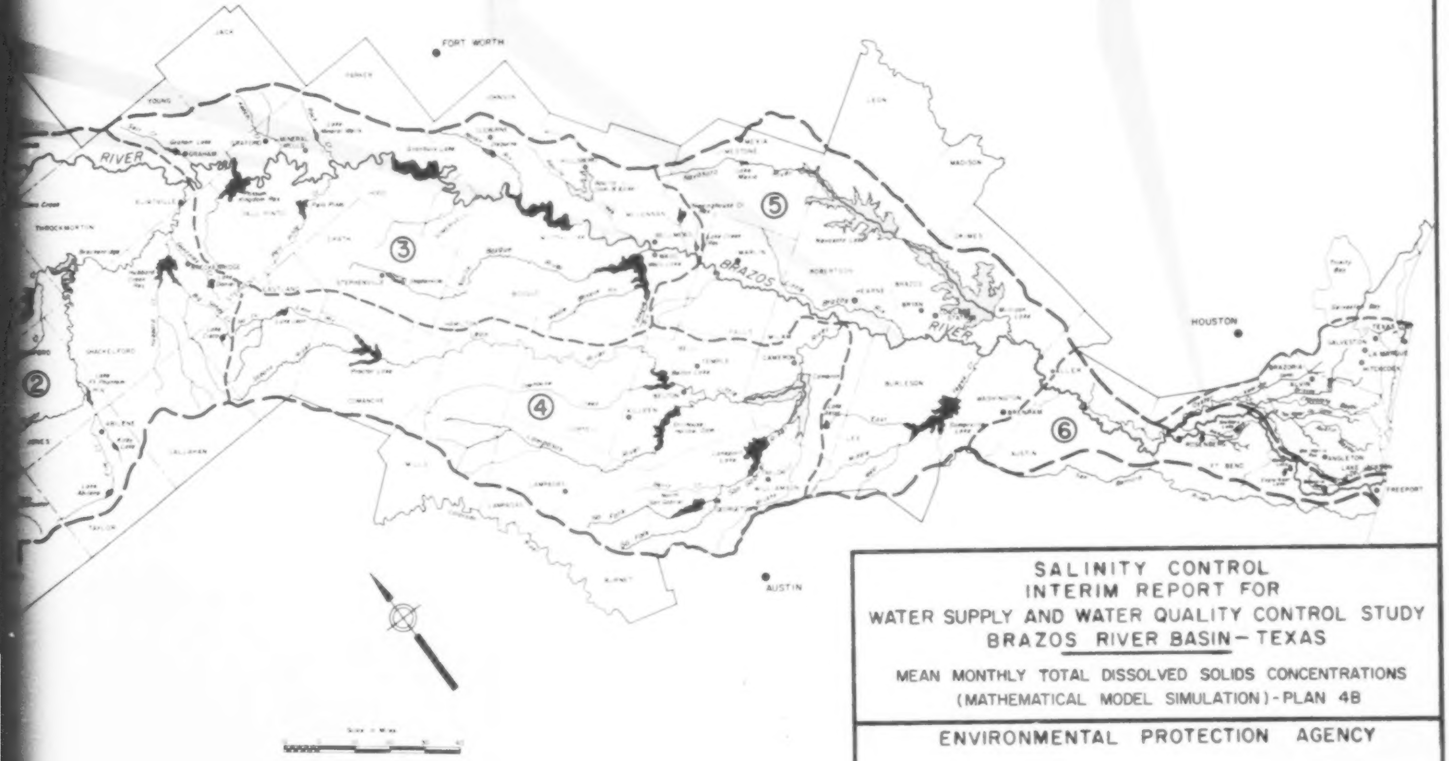

TEXAS
NEW MEX
BRAZOS
RIVER
①
②
③
JACK
FORT WOR
PARKER
BAYLOR
YOUNG
KNOX
KING
FLOYD
DICKENS
CASTRO
PARMER
LAMB
HALE
CROSBY
CURRY
BAILEY
ROOSEVELT
COCHRAN
HOCKLEY
LUBBOCK
LYNN
GARZA
KENT
SCURRY
FISHER
NOLAN
TAYLOR
JONES
CALLAHAN
SHACKELFORD
THROCKMORTON
EASTLAND
ERATH
PALO PINTO
HOOD
COMANCHE
MILLS
HAMILTON
PLAINVIEW
LITTLEFIELD
LEVELLAND
TAHOKA
O'DONNELL
SEYMOUR
GRAHAM
STAMFORD
ABILENE
SWEETWATER

USGS STATION No. 1090



USGS STATION No. 1140




FORT WORTH
RIVER
BRAZOS
RIVER
HOUSTON
AUSTIN
FREEPORT
②
③
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SALINITY CONTROL
INTERIM REPORT FOR
WATER SUPPLY AND WATER QUALITY CONTROL STUDY
BRAZOS RIVER BASIN – TEXAS

MEAN MONTHLY TOTAL DISSOLVED SOLIDS CONCENTRATIONS
(MATHEMATICAL MODEL SIMULATION) - PLAN 4B

ENVIRONMENTAL PROTECTION AGENCY

REGION VI DALLAS, TEXAS

FIGURE AIII-3

TABLE AIII-1

SURFACE WATER QUALITY PREDICTION (PLAN 4B)

Station (Figure V-2)	Stream and Location	Quality Prediction (2020 Conditions)					Simulation Model Quality				
		Potability Scale Classification					Percent of Time Equaled or Exceeded				
		Excellent	Good	Fair	Poor	Unacceptable	10	25	50	75	90
		% of Time Mean Monthly Concentration Will Be In Class					Mean Monthly Concentration (mg/1) (2020 Conditions With 1941-62 Runoff)				
825	Brazos River at Seymour			20	14	66					
	Sulfate						630	560	435	325	245
	Chloride						1260	1000	660	320	180
	Dissolved Solids						3100	2625	1750	1125	825
890	Brazos River near Palo Pinto		16	66	18						
	Sulfate						345	315	275	210	105
	Chloride						315	290	245	215	175
	Dissolved Solids						1035	960	830	735	585
965	Brazos River at Waco	12	52	36							
	Sulfate						250	195	120	80	55
	Chloride						215	180	115	75	55
	Dissolved Solids						825	710	490	375	280
1090	Brazos River near Bryan	42	53	5							
	Sulfate						150	110	75	40	30
	Chloride						145	115	70	45	30
	Dissolved Solids						600	490	340	230	175
1140	Brazos River at Richmond	48	46	6							
	Sulfate						135	105	65	40	30
	Chloride						155	115	65	40	25
	Dissolved Solids						610	440	300	225	185

be unacceptable approximately 66 percent of the time, poor approximately 14 percent of the time and fair only 20 percent of the time. Development of municipal supplies at this point would not be recommended. The quality would be acceptable for other uses such as selective use for irrigation, livestock watering and mining.

At Station 890 the quality will range from Good to Poor, is poor approximately 18 percent of the time, fair approximately 66 percent of the time and good approximately 16 percent of the time. Satisfactory municipal supplies could be withdrawn at this point by selective pumping. The quality compares favorably with municipal supplies currently in use in the general locality. Larger municipalities could use water from this point for mixing with existing supplies.

At Station No. 965 the quality will range from Excellent to Fair, is fair approximately 36 percent of the time, good approximately 52 percent of the time, and excellent approximately 12 percent of the time. Municipal supplies withdrawn at this point would be very satisfactory. The quality compares favorably with municipal groundwater supplies currently used in the general locality, in fact, in many instances the Brazos River water would be more desirable than the groundwater supplies and would meet U. S. Public Health Service Drinking Water Standards - 1962 approximately 50 percent of the time.

At Station No. 1090 the quality will range from Excellent to Fair, is fair approximately 5 percent of the time, good approximately 53 percent of the time and excellent approximately 42 percent of the time. Municipal supplies withdrawn at this point would meet U. S. Public Health Service Drinking Water Standards - 1962 approximately 78 percent of the time.

At Station No. 1140 the quality will range from Excellent to Fair, is fair approximately 6 percent of the time, good approximately 46 percent of the time, and excellent approximately 48 percent of the time. Municipal supplies withdrawn at this point would meet U. S. Public Health Service Drinking Water Standards - 1962 approximately 76 percent of the time.

It can be concluded from our study that construction of the proposed salinity control project (Plan 4B) will result in a substantial reduction of the degradation of main stem resources. Brazos River Basin water resources transported in the main stem could be withdrawn at any point from Possum Kingdom Reservoir to the mouth of the river for municipal water supplies. Plan 4A will provide more desirable quality conditions than Plan 4B, the latter plan will allow full utilization of the main stem resources in and below Granbury Lake. It may also be possible to gain full utilization of resources above Granbury Lake to include Possum Kindgom Reservoir resources through selective pumping and mixing with other supplies.